49th Annual Meeting of the Division of Plasma Physics

Orlando, Florida

http://www.aps.org/meetings/unit/dpp

Monday, November 12, 2007 8:00AM - 9:00AM –

Session AR1 Review: Gyrokinetic Theory and Simulation of Experiments Rosen Centre Hotel Junior Ballroom

8:00AM AR1.00001 Gyrokinetic Theory and Simulation of Experiments[1] GREGORY W. HAMMETT, Princeton Plasma Physics Laboratory — There has been interesting and important progress recently in the development of 5-dimensional continuum and PIC gyrokinetic simulations of turbulent transport in tokamaks [1-3]. The mechanisms driving this turbulence will be illustrated with intuitive physical pictures and visualizations from simulations. This also gives insight into methods to reduce turbulence that are being studied in experiments and simulations. 5-dimensional plasma turbulence is a very challenging problem, but is becoming feasible because of the exponential growth in computer power and advances in algorithms and theory. These advances include the gyrokinetic equations themselves (a rigorous expansion of the full equations that average over high-frequency gyromotion while retaining nonlinearities) and computational techniques such as high-order algorithms, efficient field-aligned coordinates, and implicit methods. The most comprehensive of these codes treat all transport channels and now include all the effects thought important for realistic calculations of the drift-wave microturbulence that occurs in the core of tokamaks: fully gyrokinetic ions and electrons, electromagnetic fluctuations, collisions, realistic geometry, ExB shear stabilization, and finite rho-star effects that can break gyro-Bohm scaling and provide non-local transport. These codes are increasingly being used to compare with and understand experimental data. Remaining challenges will also be described, including more extensive comparisons (such as with non-steady-state phenomena and fluctuation measurements), multiscale couplings (such as low-n MHD and turbulence), and the complex edge of fusion devices.

[1] W. Dorland, F. Jenko, M. Kotschenreuther, B.N. Rogers, Phys. Rev. Lett. (2000)
[2] J. Candy, R.E. Waltz, Phys. Rev. Lett. (2003)
[3] Y. Chen, S.E. Parker, B.I. Cohen, A.M. Dimits et al., Nucl. Fus. (2003)

[1]Supported by US DOE contract DE-AC02-76CH03073.

Monday, November 12, 2007 9:30AM - 12:30PM –

Session BI1 Pedestal, SOL and Divertor Rosen Centre Hotel Junior Ballroom

9:30AM BI1.00001 Critical gradients and plasma flows in the edge plasma of Alcator C-Mod[1] , BRIAN LABOMBARD, MIT Plasma Science and Fusion Center — Recent experiments in both L- and H-mode plasmas on Alcator C-Mod have lead to a fundamental shift in our views of edge transport physics: transport in the 'near' scrape-off-layer (SOL) region may be more appropriately described in terms of a critical gradient phenomena rather than a diffusive and/or convective transport paradigm. L-mode pressure gradients, normalized by the square of the poloidal magnetic field strength (i.e., α_{MHD}) appear invariant in plasmas with the same normalized collisionality, despite vastly different currents and magnetic fields. These data suggest that local gradients are pinned to a 'critical gradient' condition, which is sensitive to local collisionality – a behavior that connects with first-principles electromagnetic fluid drift turbulence simulations [1]. H-mode pedestal gradients are found to follow a nearly identical scaling [2]. Thus, the near SOL, which forms the base of the H-mode pedestal, may play a key role in its creation. Prior to an L-H transition, strong SOL plasma flows are found to set a flow boundary condition for the confined plasma [3]. With favorable $Bx\nabla B$ direction (i.e., $Bx\nabla B$ pointed toward active x-point) these flows tend to spin the plasma in the co-current direction, perhaps reducing the L-H threshold power. Indeed, we find the edge profiles of the L-mode target plasmas to be fundamentally different, depending on the x-point topology: higher values of α_{MHD} are observed for favorable $Bx\nabla B$ direction, independent of the direction of B – supporting evidence that SOL flows play a role in affecting the observed 'critical gradient' value.

[1] LaBombard, B., *et al.*, Nucl. Fusion **45** (2005) 1658
[2] Hughes, J.W., *et al.*, Phys. Plasmas **13** (2006) 056103
[3] LaBombard, B., *et al.*, Nucl. Fusion **44** (2004) 1047.

[1]supported by U.S. D.o.E. Coop. Agreement DE-FC02-99ER54512

10:00AM BI1.00002 Effect of Island Overlap on ELM Suppression by Resonant Magnetic Perturbations in DIII-D[1] , M.E. FENSTERMACHER[2], Lawrence Livermore National Laboratory — Recent DIII-D experiments show that the degree of magnetic island overlap in the plasma edge is a good predictor for suppression of edge-localized modes (ELMs), consistent with theoretical expectations. For fixed resonant magnetic perturbation (RMP) strength, ELM suppression is obtained over a finite window in the edge safety factor (q_{95}) indicating a resonant effect. In H-mode plasmas, ELM suppression is obtained over an increasing range of q_{95} by either increasing the RMP strength that produces the islands, or by adding $n = 1$ perturbations to "fill in" islands across the edge plasma. Large Type-I ELMs are completely suppressed by applying $n = 3$ RMPs in the presence of $n = 1$ error-field correction and small $n = 2$ and 3 field-error components in plasmas with electron pedestal collisionality of ∼0.1 and shape similar to ITER. In these experiments, the region of island overlap is changed by varying either: 1) the strength of the applied $n = 3$ RMP, 2) the edge q-profile, 3) the combination of $n = 3$ and $n = 1$ perturbations, or 4) the up-down parity of the applied $n = 3$ RMP. Each case agrees with theoretical expectations that the island overlap region width (vacuum fields) needs to be at least several times the width of the pedestal to completely eliminate ELMs. Theory predicts that the plasma response in rotating plasmas reduces the RMP amplitude from the vacuum level (RMP screening). Experiments to validate this theory have examined the detailed dependence of ELM suppression on the width of the island overlap region for two different values of edge toroidal rotation. Experimental validation of theoretical models for ELM suppression represents an important scientific advance that will provide the foundation for designing ELM control systems in future devices.

[1]Supported by US DOE under W-7405-ENG-48 and DE-FC02-04ER54698.
[2] for the DIII-D Team

10:30AM BI1.00003 Influence of Beta, Shape, and Rotation on the H-mode Pedestal Height in DIII-D[1] , A.W. LEONARD, General Atomics — Recent experiments on DIII-D aimed at improving our understanding of the H-mode pedestal have shown that the observed pedestal gradient and pedestal width are sensitive to variations in plasma shape and global β but relatively insensitive to plasma rotation. These dependencies are critical to the extrapolation of present results to ITER due to the sensitivity of fusion performance on pedestal height. Using single parameter scans to isolate these effects, the pedestal pressure was observed to increase as either plasma shaping or global β was increased due to an increase in the width and the gradient of the pedestal pressure. In both cases, stability analysis indicated that the increased pressure gradient is consistent with peeling/ballooning theory. Stronger shaping increases the edge stability limit, allowing the pedestal pressure gradient to increase. At the same time, the pedestal width grows with the increasing pressure gradient until the MHD stability limit is reached and an ELM occurs. In the same manner, increased β improves the edge stability limit through increased Shafranov shift, with the pedestal gradient and width increasing. The increase in pedestal width at higher total pedestal pressure is correlated with a larger ion gyroradius as suggested by a number of theories. Gyroradius dependence will be examined with respect to previous results and scaling of the pedestal height to ITER. Increased toroidal rotation was observed to have minimal impact on the pedestal height even though core energy confinement improved. Increased toroidal rotation does not significantly change the stability limit, resulting in the pedestal width and gradient remaining unchanged. These results suggest that the improvement in core confinement as rotation increases is independent of pedestal performance.

[1]Supported by US DOE under DE-FC02-04ER54698.

11:00AM BI1.00004 Progress in ITER-relevant exhaust physics at JET[1] , RICHARD PITTS, Centre de Recherches en Physique des Plasmas, EPFL, Association Euratom-Confédération Suisse, 1015 Lausanne, Switzerland — Plasma boundary research during the 2006-2007 campaigns at JET has made advances in several ITER-relevant exhaust physics issues. On the critical question of fuel retention, dedicated gas balance experiments provide unequivocal evidence for long term retention of 10-20% in both L-mode and ELMing H-mode, in fair agreement with that obtained from campaign averaged post-mortem analysis. In-situ quartz microbalance (QMB) techniques coupled with visible spectroscopy and modelling show that long range migration of carbon to remote areas and is a major contributor to this retention. The QMB data also register an ELM induced erosion rate increasing exponentially with ELM energy. Large Type I ELMs (up to ~1MJ), comparable to the smallest expected in ITER, provoke divertor and X-point radiation in the range 50-100% of the ELM energy with an in-out asymmetry favouring the inner divertor. This is consistent with the observed trend for the ELM to deposit more energy on the inboard target for normal field direction and the presence of redeposited layers, which have lower threshold for ablation under high power fluxes. The magnitude and time variation of these power fluxes can be reproduced quantitatively by new PIC simulations of kinetic transport parallel to the field in the SOL. The spatial patterns and magnitudes of energy deposition during ELMs have been measured for the first time on JET main chamber wall surfaces using IR thermography, confirming the presence of field aligned filaments carrying a small fraction of the ELM energy. Meanwhile, the small, convective ELMs previously found in JET at ITER relevant pedestal collisionalities, have been recovered in the new MarkIIHD divertor configuration and a clear threshold in q_{95} identified for their occurrence.

[1]This work was funded in part by the Swiss National Science Foundation.

11:30AM BI1.00005 Divertor Heat Flux Reduction and Detachment in the National Spherical Torus eXperiment.[1] , VSEVOLOD SOUKHANOVSKII, Lawrence Livermore National Laboratory — Steady-state handling of the heat flux is a critical divertor issue for both the International Thermonuclear Experimental Reactor and spherical torus (ST) devices. Because of an inherently compact divertor, it was thought that ST-based devices might not be able to fully utilize radiative and dissipative divertor techniques based on induced power and momentum loss. However, initial experiments conducted in the National Spherical Torus Experiment in an open geometry horizontal carbon plate divertor using 0.8 MA 2-6 MW NBI-heated lower single null H-mode plasmas at the lower end of elongations κ=1.8-2.4 and triangularities δ=0.45-0.75 demonstrated that high divertor peak heat fluxes, up to 6-10 MW/ m^2, could be reduced by 50-75% using a high-recycling radiative divertor regime with D_2 injection. Furthermore, similar reduction was obtained with a partially detached divertor (PDD) at high D_2 injection rates, however, it was accompanied by an X-point MARFE that quickly led to confinement degradation. Another approach takes advantage of the ST relation between strong shaping and high performance, and utilizes the poloidal magnetic flux expansion in the divertor region. Up to 60 % reduction in divertor peak heat flux was achieved at similar levels of scrape-off layer power by varying plasma shaping and thereby increasing the outer strike point (OSP) poloidal flux expansion from 4-6 to 18-22. In recent experiments conducted in highly-shaped 1.0-1.2 MA 6 MW NBI heated H-mode plasmas with divertor D_2 injection at rates up to 10^{22} s^{-1}, a PDD regime with OSP peak heat flux 0.5-1.5 MW/m^2 was obtained without noticeable confinement degradation. Calculations based on a two point scrape-off layer model with parameterized power and momentum losses show that the short parallel connection length at the OSP sets the upper limit on the radiative exhaust channel, and both the impurity radiation and large momentum sink achievable only at high divertor neutral pressures are required for detachment.

[1]Supported by US DOE under W-7405-Eng-48.

12:00PM BI1.00006 Dynamics and generation mechanisms of meso-scale structures in tokamak edge plasmas.[1] , SERGEI KRASHENINNIKOV, University of California, San Diego — In recent years, it became clear that intermittent convective-like transport associated with meso-scale coherent structures extended along the magnetic field lines is often dominant in the cross-field transport of tokamaks, stellarators, and linear devices. Such structures can propagate in a ballistic way toward the wall for the distance of tens of centimeters and can strongly enhance plasma energy and particle transport and plasma-wall interactions. The apparent examples of such meso-scale structures in the edge and the Scrape-off Layer (SOL) plasmas are Edge Localized Modes (ELMs) and blobs, and pellet clouds in the core of fusion devices. Significant amount of theoretical and computational work on the physics of coherent structures has been done to date. It was found that in many cases, an effective gravity (e.g. due to curvature effects in a tokamak) plays a very important role in the dynamics of the evolution of the structures. It turns out that reduced 2D models with different closures accounting for the parallel plasma dynamics give tractable and useful approach to understand the main features of meso-scale structures. In particular, the dynamics of the propagation of ELMs and blobs in the SOL plasma is understood rather well. However, while the origin of ELMs is widely assumed to be due to peeling-ballooning instabilities, the generation mechanism (-s) of blobs are still dim. Here we review the models of blobs developed so far and present new both analytic and modeling results describing the mechanisms of the blob generation triggered by sub-critical phenomena related to the ballooning drive.

[1]Work in part performed under auspices of USDOE by UCSD grants No. DE-FG02-04ER54739.

Monday, November 12, 2007 9:30AM - 12:30PM –
Session BI2 Simulation of Magnetic Fusion Plasmas Rosen Centre Hotel Salon 3/4

9:30AM BI2.00001 Closure of computational fluid models with evolving-background δf kinetics[1]

, D.C. BARNES, CIPS, University of Colorado — A new method of applying simulation particles to close implicit time-dependent nonlinear extended-MHD modeling has been formulated, analyzed, and tested. The new method has three important features that will likely prove useful for any evolving-background δf simulation. First, the fluid equations should be closed with particle information at the momentum-density level to minimize statistical noise from closure terms. Second, the particle motion is described by a particular velocity that represents dynamics without thermal forces, separating the kinetic dynamics from the fluid dynamics. With the use of this particular velocity, there exists symmetry between the δf weight evolution equation and the fluid closure. Third, an optimal prescription for particle shape in velocity space can be derived using Hermite polynomials. The symmetry and optimal shaping together ensure that the numerical kinetic distortion acquires no low-order moments, analogous to the analytical Chapman-Enskog-like approach. They also lead to a conserved energy integral for the discrete nonlinear system, and the r.m.s. particle weight is bounded. With this advance in computation, combined particle-fluid simulation of low-frequency extended-MHD dynamics with majority ion kinetics is now possible. The new method has been implemented for kinetic ion dynamics with fluid electron modeling in the 2D code IMP2. The method successfully reproduces dynamics where the electric field is perpendicular to the magnetic field, including kinetic stabilization of the isothermal g-mode in a slab. Extensions to include temperature gradient and arbitrary polarization are described. Co-author: W. D. Nystrom, *Coronado Consulting*, Lamy, NM

[1]Work sponsored by Office of Fusion Energy Sciences.

10:00AM BI2.00002 Fully 3D RWM and Feedback Stabilization Studies for ITER and AUG[1]

, ERIKA STRUMBERGER, Max-Planck-Institut fuer Plasmaphysik, Garching, Germany — A high β-limit is a necessary condition for a working power plant. However, instabilities associated with ideal internal and external modes limit the plasma beta. External kink modes of MHD equilibria can be stabilized by a perfectly conducting wall sufficiently close to the plasma. In case of a real wall with non-zero resistivity the modes become unstable and grow on the resistive timescale of magnetic field diffusion through the wall. The growth rates of resistive wall modes (RWMs) are typically orders of magnitude smaller than of kink modes in the no-wall case so that the stabilization of RWMs by an active feedback system becomes feasible. Some axisymmetric approaches already exist which deal with this problem numerically. Nevertheless, because of experimental needs a realistic external wall has a complex three-dimensional shape. Usually, it is a multiply-connected structure. Besides the resistive wall also the feedback coils violate the axisymmetry of a tokamak configuration. Therefore, a three-dimensional, numerical treatment of the feedback stabilization problem is necessary. For this reason, starting from a stellarator code (CAS3D code) we developed the fully three-dimensional stability code STARWALL, and the feedback optimization code OPTIM. With these codes, we are able to compute the growth rates of resistive wall modes in the presence of non-axisymmetric, multiply-connected wall structures (i.e. with holes), and to model the active feedback stabilization of these modes. Analogue to the axisymmetric approaches, the problem is divided into two parts. In the open-loop part, the complete set of eigenvalues and eigenfunctions of the plasma-resistive-wall system without feedback currents is determined. Then, in the closed-loop part an initial value problem is formulated for the time evolution of the RWMs and the currents in the feedback coils. The feedback logics controlled by a set of free parameters specifies the interaction between the feedback currents and the RWMs. After choosing their values, the effectiveness of the feedback can be studied by solving the characteristic equation of the closed-loop system. The procedure has been implemented numerically (STARWALL code) and applied to resistive wall configurations for ITER and ASDEX Upgrade. For an optimal choice of the feedback parameters, the OPTIM code has been developed which optimizes the stability of a truncated closed-loop system under variations of the free parameters.

[1]EURATOM Association

10:30AM BI2.00003 Scalable algorithms for 3D extended MHD.[1]

, LUIS CHACON, Los Alamos National Lab — In the modeling of plasmas with extended MHD (XMHD), the challenge is to resolve long time scales while rendering the whole simulation manageable. In XMHD, this is particularly difficult because fast (dispersive) waves are supported, resulting in a very stiff set of PDEs. In explicit schemes, such stiffness results in stringent numerical stability time-step constraints, rendering them inefficient and algorithmically unscalable. In implicit schemes, it yields very ill-conditioned algebraic systems, which are difficult to invert. In this talk, we present recent theoretical and computational progress that demonstrate a scalable 3D XMHD solver (i.e., $CPU \sim N$, with N the number of degrees of freedom). The approach is based on Newton-Krylov methods, which are preconditioned for efficiency. The preconditioning stage admits suitable approximations without compromising the quality of the overall solution. In this work, we employ optimal ($CPU \sim N$) multilevel methods on a parabolized XMHD formulation, which renders the whole algorithm scalable. The (crucial) parabolization step is required to render XMHD multilevel-friendly. Algebraically, the parabolization step can be interpreted as a Schur factorization of the Jacobian matrix, thereby providing a solid foundation for the current (and future extensions of the) approach. We will build towards 3D extended MHD[2,3] by discussing earlier algorithmic breakthroughs in 2D reduced MHD[4] and 2D Hall MHD.[5]

[1]Supported by the Applied Math Research Program, Office of Advanced Scientific Computing, DOE
[2]L. Chacón, *Comput. Phys. Comm.*, **163** (3), 143-171 (2004)
[3]L. Chacón et al., *33rd EPS Conf. Plasma Physics*, Rome, Italy, 2006
[4]L. Chacón et al., *J. Comput. Phys.* **178** (1), 15- 36 (2002)
[5]L. Chacón et al., *J. Comput. Phys.*, **188** (2), 573-592 (2003)

11:00AM BI2.00004 Nonlinear Hybrid Simulations of Multiple Energetic Particle driven Alfven Modes in Toroidal Plasmas[1]

, GUOYONG FU, Princeton Plasmas Physics Laboratory — Understanding of nonlinear behavior of energetic particle-driven instabilities in tokamaks is of fundamental importance for burning plasmas. Here we report recent advances in self-consistent nonlinear simulations of fast beam ion-driven Alfven modes in NSTX and DIII-D using the extended MHD code M3D [1]. In the hybrid model, the thermal electrons and ions are treated as an ideal fluid while the energetic species is described by either drift-kinetic equation or gyrokinetic equation. The effects of energetic particles are coupled to the MHD equations via the stress tensor term in the momentum equation. The hybrid code has been recently applied to study nonlinear dynamics of fishbone instability [2]. The code was also used to simulate nonlinear evolution of a single beam-driven TAE mode in NSTX. The result showed a weak frequency chirping about 20% consistent with experimental measurement [3]. In this work, we use the M3D code to simulate beam ion driven Alfven modes in NSTX plasmas with multiple unstable Alfven modes. It is found that mode saturation level of each mode can be enhanced significantly by presence of other unstable modes indicating strong nonlinear interaction between different modes. It is also found that a linearly stable n=2 mode can be nonlinearly driven by an n=1 mode at significant mode amplitude. These results together with simulation results of beam ion-driven Alfven modes in DIII-D reversed shear plasmas [4] will be presented.

[1] W. Park, E.V. Belova, G.Y. Fu et al., Phy. Plasmas 6, 1796 (1999)
[2] Fu, GY, Park, W, Strauss HR et al. PHYSICS OF PLASMAS 13, 052517 (2006)
[3] Fu GY, Breslau J, Fredrickson E et al. ,Proceedings of 2004 IAEA Fusion Energy Conference, Vilamoura, Portugal, Paper TH/P4-38.
[4] M.A., Van Zeeland, G.J. Kramer, M.E. Austin et al., Phys. Rev. Lett. 97, 135001 (2006).

[1]This work has been conducted under DOE Contract No. DE-AC02-76-CH3073

11:30AM BI2.00005 Coarse-graining phase-space in delta-f Particle-in-Cell (PIC) simulation[1]

, YANG CHEN, University of Colorado at Boulder — Particle weights in a δf PIC simulation slowly grow in time even after the turbulent fluxes reach a steady state. This can eventually lead to discrete particle noise at long times. We present a solution to this problem. Growing weights are the result of balancing the flux in a truly collisionless simulation. Collisions as currently implemented in PIC models via Monte-Carlo do not reduce the growing weight problem [2]. Since weight growth is manifestation of phase-space filamentation, the weight level can be reduced by simply periodically coarse-graining the distribution function in phase space. A five-dimensional phase-space grid is used to facilitate the coarse-graining procedure (CGP). δf is periodically deposited on the 5-D grid, then re-evaluated at the particle position using interpolation. Any discontinuity of δf in time arising from CGP is reduced by resetting only a small fraction of the particle weight. CGP effectively introduces dissipation into the otherwise dissipation-less PIC method. An estimate of the numerical diffusion due to this smoothing procedure is provided in the limit of large particle number. CGP is demonstrated to effectively suppress the long-term increase of the particle weights in ITG simulations, while keeping the turbulent flux unchanged. Spectral analysis indicates that the reduction in particle weights is mainly due to the elimination of the short scale structures in the density fluctuations. Large scale density fluctuations that account for the turbulent fluxes are not affected. We have implemented CGP in the GEM code and applied it to the study of beta-scaling of turbulent transport in core plasmas, as well as, the simulation of edge plasmas with strong density and temperature gradients. Both of these problems were previously difficult to model in flux-tube simulations.

[1] In collaboration with Scott E. Parker (CU-Boulder), Gregory Rewoldt (PPPL) , Seung-Hoe Ku, C-S Chang (New York Universty). Work supported by SciDAC Center for Plasma Edge Simulation and Center for Gyrokinetic Particle Simulation.
[2] Y. Chen and S. E. Parker, J. Comput. Phys. 220 839 (2007)

12:00PM BI2.00006 First Transport Code Simulations using the TGLF Model[1]

, J.E. KINSEY, General Atomics — The first transport code simulations using the newly developed TGLF theory-based transport model [1,2] are presented. TGLF has comprehensive physics to approximate the turbulent transport due to drift-ballooning modes in tokamaks. The TGLF model is a next generation gyro-Landau-fluid model that includes several recent advances that remove the limitations of its predecessor, GLF23. The model solves for the linear eigenmodes of trapped ion and electron modes (TIM, TEM), ion and electron temperature gradient (ITG, ETG) modes and finite beta kinetic ballooning (KB) modes in either shifted circle or shaped geometry [1]. A database of over 400 nonlinear GYRO gyrokinetic simulations has been created [3]. A subset of 140 simulations including Miller shaped geometry has been used to find a model for the saturation levels. Using a simple quasilinear (QL) saturation rule, we find remarkable agreement with the energy and particle fluxes from a wide variety of GYRO simulations for both shaped or circular geometry and also for low aspect ratio. Using this new QL saturation rule along with a new ExB shear quench rule for shaped geometry, we predict the density, temperature, and toroidal rotation profiles in a transport code and compare the results against experimental data in the ITPA Profile Database. We examine the impact of the improved electron physics in the model and the role of elongation and triangularity on the predicted profiles and compare to the results previously obtained using the GLF23 model.
[1] G.M. Staebler, J.E. Kinsey, and R.E. Waltz, Phys. Plasmas **12**, 102508 (2005).
[2] G.M. Staebler, J.E. Kinsey, and R.E. Waltz, to appear in Phys. Plasmas, May(2007).
[3] The GYRO database is documented at fusion.gat.com/theory/gyro.

[1] Supported by US DOE under DE-FG03-95ER54309.

Monday, November 12, 2007 9:30AM - 12:30PM –

Session BO3 Beams, Instabilities, and Turbulence Rosen Centre Hotel Salon 9/10

9:30AM BO3.00001 Plans for near-term neutralized drift compression experiments[1]

, P.A. SEIDL, LBNL, J.J. BARNARD, LLNL, J.E. COLEMAN, LBNL, UCB, A. FALTENS, LBNL, A. FRIEDMAN, LLNL, E.P. GILSON, PPPL, J.Y. JUNG, E.P. LEE, M. LEITNER, P.K. ROY, LBNL, A.B. SEFKOW, PPPL, J.L. VAY, W.L. WALDRON, LBNL, D.R. WELCH, Voss Scientific, HIFS-VNL COLLABORATION — One approach to target heating experiments with space-charge dominated ion beams is to simultaneously longitudinally bunch and transversely focus the beam. Axial compression leading to ~100X current amplification and simultaneous radial focusing have led to encouraging energy deposition approaching, but still short of, intensities required for eV-range target heating experiments. We discuss the status of several improvements and associated beam diagnostics that are under development to reach the higher beam intensities, including: (1) greater axial compression via a higher Δv/v velocity ramp using a new bunching module; (2) improved centroid control via beam steering dipoles; (3) time-dependent focusing elements to correct considerable chromatic aberrations; and (4) plasma injection improvements to maintain a plasma density always greater than the beam density.

[1] This work was supported by the U.S. D.O.E. under Contracts DE-AC02-05H11231, DE-AC02-76CH3073, and W-7405-ENG-48.

9:42AM BO3.00002 A space-charge neutralizing plasma channel for an intense beam[1]

, P.K. ROY, P.A. SEIDL, LBNL, J.J. BARNARD, LLNL, J.E. COLEMAN, J.A. DUERSCH, LBNL, UCB, A. FRIEDMAN, LLNL, E.P. GILSON, PPPL, J.Y. JUNG, M. LEITNER, B.G. LOGAN, LBNL, D. OGATA, LBNL, UCB, A.B. SEFKOW, PPPL, W.L. WALDRON, LBNL, D.R. WELCH, Voss Scientific, HIF-VNL COLLABORATION — Ion bunches have been suggested as an attractive means to heat matter to the warm dense matter, or strongly coupled plasma, regime (Temperature ~ 0.1 to 10 eV). For a K^+ beam at 0.4 MeV, ~1 J/cm^2 is required to reach 1 eV in solid Aluminum. Also the pulse duration must be short (<~ 2 ns) to avoid hydrodynamic cooling. A spot radius ~0.5 mm, and current ~10 A, would enable this flux level and pulse duration. The required current will be achieved by compressing the beam axially. To further increase the beam intensity on target, we will use an 8T solenoid, filled with plasma injected from filtered cathodic arc plasma sources. The Neutralized Drift Compression Experiment at LBNL is intended to test these neutralized focusing techniques with the goal of reaching target temperatures ~0.5 eV. Experimental measurements, including the on-axis plasma density distribution and the beam density distribution, will be presented.

[1] This work was supported by the U.S. D.O.E. under Contracts DE-AC02-05H11231, DE-AC02-76CH3073, and W-7405-ENG-48.

9:54AM BO3.00003 Improved neutralized compression and focusing of an intense ion beam using a final focus solenoid

, J.E. COLEMAN, P.A. SEIDL, J.A. DUERSCH, D. OGATA, P.K. ROY, K. VAN DEN BOGERT, LBNL, Berkeley, CA 94720, USA, A.B. SEFKOW, E.P. GILSON, PPPL, New Jersey 08543, USA, D.R. WELCH, Voss Scientific, Albuquerque, NM 87108, USA — Future target heating experiments with space-charge dominated ion beams require simultaneous longitudinal bunching and transverse focusing. We present an experiment to simultaneously focus a singly charged potassium ion beam at LBNL. The space charge of the beam must be neutralized so only emittance limits the focused beam intensity. An induction bunching module provides a head-to-tail velocity ramp upstream of a neutralizing plasma column and a final focusing solenoid. The beam parameters are tuned with a four-solenoid lattice to transport the neutralized compressing beam into a final focus solenoid which transversely focuses the beam at the target plane. We have improved the axial focus (> 100x axial compression, < 2 ns pulses) and reduced the beam spot size. A comparison of experimental and modeling results are presented. (This work was supported by the U.S. D.O.E. under DE-AC02-05H11231 and DE-AC02-76CH3073 for HIFS-VNL)

10:06AM BO3.00004 Planning for NDCX-II, a next-step platform for ion beam-driven Warm Dense Matter studies[1] , A. FRIEDMAN, J.J. BARNARD, D.P. GROTE, LLNL, E. HENESTROZA, M. LEITNER, B.G. LOGAN, W.L. WALDRON, S.S. YU, LBNL, R.C. DAVIDSON, I. KAGANOVICH, PPPL — The Heavy Ion Fusion Science Virtual National Laboratory, a collaboration of LBNL, LLNL, and PPPL, has achieved 60-fold temporal pulse compression of ion beams on the Neutralized Drift Compression eXperiment (NDCX) at LBNL. Here, a velocity "tilt" is imparted to the beam by a ramped voltage pulse as it traverses an induction gap; the beam's tail then catches up with its head in a plasma environment that provides the needed neutralization. Initial studies of matter heated by low-energy ions are beginning on NDCX. We seek to experimentally study uniformly heated foils for basic Warm Dense Matter physics, and key aspects of ion direct drive for inertial fusion. These goals require an improved platform, NDCX-II, and this talk will describe our progress and planning thereof, with an emphasis on simulation studies of beam dynamics.

[1]Work performed under auspices of U.S. DoE by the University of CA, LLNL and LBNL under Contracts W-7405-Eng-48 and DE-AC02-05CH11231, and PPPL under Contract DE-AC02-76CH03073.

10:18AM BO3.00005 Further Development of the Gyrotron- Powered Pellet Accelerator , FRANCIS PERKINS, University of Colorado — The Gyrotron-Powered Pellet Accelerator provides an enabling technology to efficiently fuel ITER with fast pellets launched from the High Field Side (HFS) separatrix. Pellet experiments have repeatedly found that fuel efficiently is high - consistent with 100%. In contrast, Low Field Side (LFS) launch experiments find efficiencies of 50% or less. This report addresses what experimental program and what material choices can be made to retain program momentum. An initial program seeks to establish that our heterogeneous approach to conductivity works, maintaining s 1 mho/m. A demonstration of acceleration can be carried out in a very simple laboratory when the pusher material D_2[Be] is replaced by LiH[C] which is a room temperature solid with a graphite particle suspension. No cryogenics or hazard chemicals. The mm-wave mirror will be graphite, the tamper is sapphire, and the payload LiD. The payload has a pellet has diameter = 3mm and a mass M = 4.4x10^{-4} kg which is 220 joules at V=1000 m/s. A barrel length of 15 cm completes the design specification.

10:30AM BO3.00006 Electron Beam Focusing Dynamics in Gas-filled Transport Cells for Radiography[1] , KELLY HAHN, B.V. OLIVER, S. PORTILLO, Sandia National Laboratories, D.R. WELCH, N. BRUNER, Voss Scientific, G. COOPER, J. MCLEAN, Atomic Weapons Establishment — At Sandia National Laboratories, investigations of intense electron beam-driven diodes for flash x-ray radiography are being conducted on the RITS-6 accelerator, 9-12 MV. One of several diodes under investigation is the paraxial diode, which employs a gas-filled transport cell to focus the beam onto a high atomic number target to generate x-rays. LSP simulations have shown that the primary limitation in spot size is attributed to the finite decay of the plasma return current which causes the beam focal position to shift axially during the timescale of the pulse, hence leading to an increased radiation spot. Time-resolved measurements of the radiation spot are reported which convey this trend.

[1]Sandia is a multiprogram laboratory, operated by Sandia Corporation, a Lockheed Martin company for the United States Department of Energy's National Nuclear Security Agency, under Contract DEAC04-94-AL85000.

10:42AM BO3.00007 Alignment between velocity and magnetic field fluctuations in the inertial range of solar wind turbulence and comparison to Boldyrev's phenomenological theory , J.J. PODESTA, A. BHATTACHARJEE, B.D. CHANDRAN, Center for Integrated Computation and Analysis of Reconnection and Turbulence, University of New Hampshire, Durham, NH 03824 — According to Boldyrev's phenomenological theory of incompressible MHD turbulence in a magnetized plasma the cascade of energy and cross-helicity from large to small scales is accompanied by an alignment between the vector velocity and magnetic field fluctuations. This alignment process is governed by the scale-by-scale conservation of energy and cross-helicity and predicts that the angle between $\delta\mathbf{v}_\perp$ and $\delta\mathbf{b}_\perp$ scales like $\lambda^{1/4}$, where λ is the length scale of the fluctuations perpendicular to the mean magnetic field. Solar wind observations show that this scaling law is approximately valid at the largest inertial range scales but breaks down at intermediate to small scales. Analysis of in-situ measurements from the Wind spacecraft at 1 AU are presented and theoretical implications of these results are discussed.

10:54AM BO3.00008 Theory for the measurement of cascade rates of energy and cross-helicity in axisymmetric incompressible MHD turbulence , MIRIAM FORMAN, Department of Physics and Astronomy, State University of New York, Stony Brook, New York, 11794, JOHN PODESTA, CHARLES SMITH, Space Science Center, University of New Hampshire, Durham, NH 03824 — A theory is presented for the experimental measurement of the turbulent cascade rates of energy and cross-helicity for incompressible MHD turbulence that is statistically homogeneous and axisymmetric about the mean magnetic field. Like Kolmogorov's four-fifths law for incompressible hydrodynamic turbulence, the theory is based on measurements of third order moments of the fluctuations at two points separated by a vector **r**. In MHD the third order moments contain combinations of velocity and magnetic field fluctuations and are proportional to the distance r when r lies in the inertial range. For axisymmetric MHD turbulence the third order moments are also functions of the angle θ between the displacement vector **r** and the mean magnetic field and the dependence on the angle must be measured to determine the cascade rates from experimental data. Tensor forms for the third order moments in axisymmetric MHD turbulence are derived and the resulting theory reveals an interesting relationship between the cascade rates and the angular dependence of the third order moments.

11:06AM BO3.00009 Self-organization and criticality of magnetotail plasma[1] , ALEXANDER MILOVANOV, Department of Physics and Technology, University of Tromso, 9037 Tromso, Norway, LEV ZELENYI, Department of Space Plasma Physics, Space Research Institute, 84/32 Profsoyuznaya, 117997 Moscow, Russia — There is a vast observational evidence that magnetic field and plasma fluctuations in the far geo-magnetic tail show a power spectral density that is best modeled by power laws with kinks around some characteristic frequencies. In-situ satellite observations have shown that the fluctuations exhibit scale-free behavior in a range of intermediate and low frequencies but with diverse scaling characteristics. Here we propose a model in which those signatures of scale invariance and power laws are explained in terms of self-organization and criticality of space plasma. In this model the global stability of the tail is provided by the ion component of the plasma, while electrons are attributed the role of a charge-neutralizing background. We discuss the mechanisms of plasma heating and energization in the magnetotail and occurrence of power-law supra-thermal tails in the electron energy distribution. Our model predictions are well inside the range of observational evidence and former theoretical arguments.

[1]This work was partially supported by the Norwegian Research Council under the project No. 171076/V30

11:18AM BO3.00010 Spatio-temporal dynamics of the magnetosphere: Mutual information function analysis[1] , SURJA SHARMA, JIAN CHEN, THANGAMANI VEERAMANI, University of Maryland, College Park — The magnetospheric response to strong driving by the solar wind is highly structured, and spatially resolved data are essential for the understanding of the spatio-temporal dynamics. The global and local features of the magnetosphere are studied using nonlinear dynamical techniques of phase space reconstruction. A database of the solar wind data from satellites and ground-based magnetometer stations is used to study the magnetospheric response to solar wind variables using mutual information functions. A key feature of the mutual information function is its ability to bring out the linear as well as nonlinear correlations and such functions are needed to study the inherently nonlinear dynamics of the magnetosphere. The spreads in the average mutual information functions computed for the different stations show strong correlations with the solar wind convective electric field and the sudden changes in the dynamic pressure. The time evolution of mutual information shows a westward expansion of the disturbed region in the night side magnetosphere, starting from the near midnight sectors. The mutual information functions are used to quantify the transfer of information among the different locations.

[1]Supported by NSF grants ATM-0318629 and DMS-0417800

11:30AM BO3.00011 Extraordinary-Mode Radiation Produced by Linear-Mode Conversion of Langmuir Waves , EUN-HWA KIM, Princeton University, IVER CAIRNS, PETER ROBINSON, University of Sydney — Linear-mode conversion (LMC) of Langmuir waves to radiation near the plasma frequency at density gradients is important for laboratory, space, and astrophysical phenomena. We study LMC in warm magnetized plasmas using numerical electron fluid simulations when the density gradient is parallel to the ambient magnetic field (B_0). We demonstrate that LMC can produce extraordinary (x) mode as well as ordinary (o) mode radiation from Langmuir waves, contrary to earlier expectations of o-mode only. Equal amounts of o- and x-mode radiation are produced in the unmagnetized limit. The x-mode efficiency decreases as B_0 increases while the o-mode efficiency oscillates due to an interference phenomenon between incoming and reflected Langmuir or z-modes. Both x- and o-mode should be produced for typical coronal and interplanetary parameters, alleviating the long-standing depolarization problem for type III solar radio bursts.

11:42AM BO3.00012 Instability of coherent whistlers propagating along field lines in the magnetosphere[1] , MARTIN LAMPE, GURUDAS GANGULI, NRL Plasma Phys. Div., GLENN JOYCE, WALLACE MANHEIMER, U. Maryland — We report on analytic and simulation studies of nonlinear instability triggered by a whistler propagating along a geomagnetic field line. For simplicity of interpretation, the electron distribution is taken to be the highly unstable ring distribution $\mathrm{f}(\mathbf{v})=\delta(\mathrm{v}_{||}-\mathrm{v}_{||0})\delta(\mathrm{v}_{\perp}-\mathrm{v}_{\perp 0})$. The variation (quadratic near the equator) of the geomagnetic field B(z) along a field line is important, even though $\lambda \quad \sim 1$ km while the field gradient scale $\sim$1000 km. The instability is triggered by an initial wave pulse of finite duration τ_p; the value of τ_p also plays an important role. Instability occurs initially at the resonant points where $\omega-\mathrm{kv}_{||}-\Omega=0$, but is carried backwards in the pulse by the stream of resonant electrons. The fresh flow of unperturbed electrons into the pulse plays an important role, and in the non-uniform B(z), phase-trapped electrons can continue to drive the nonlinear stage of the instability, which is characterized by both growth and strong spatio-temporal variations of the wave frequency.

[1]Supported by ONR

11:54AM BO3.00013 Interaction of electric field with plasma clouds in lower ionosphere[1] , YAKOV DIMANT, MEERS OPPENHEIM, Boston University — At the lower-E/upper-D altitudes between 80 and 120 km, the ionospheric plasma density is low, especially at nighttime. At these altitudes, meteor plasma trails and sporadic-E layers are often present. The former, highly elongated and slowly diffusing structures have the lengths of several kilometers, the lifetimes from 1s to several minutes, and they fill the entire lower ionosphere. The latter, pancake-like clouds are much rarer, but they span tens to thousands of kilometers in horizontal direction and live several hours and longer. In the lower ionosphere, especially at high latitudes or near the magnetic equator, an external electric field often occurs. This field polarizes the highly conducting clouds, redistributes the electrostatic potential, and generates currents both within and around the cloud. Using a universal approach, we have developed a 3D analytical theory of these phenomena. The theory predicts significant amplification of the electric field in the near-cloud region and strong currents. This is important for generation of plasma instabilities, electron heating, and magnetosphere-ionosphere coupling.

[1]Work supported by NSF grants ATM-0332354, ATM-0334906, and ATM-0334256

12:06PM BO3.00014 Modeling Plasma Interactions with Satellite-Borne Instrumentation[1] , JEFFREY KLENZING, GREGORY EARLE, RODERICK HEELIS, The University of Texas at Dallas — We have developed a simulation of ion interactions with the biased grids of the Retarding Potential Analyzer (RPA), which is one of the fundamental instruments of space science. RPAs have successfully been flown on spacecraft since the late 1950's, including Sputnik III, the Viking lander, and the DMSP family of satellites. The RPA measures the distribution of particle flux as a function of ion energy by using biased grids as an energy filter for collected particles. In order to fit collected data to physical parameters, the interaction of charged particles with the biased grid must be studied thoroughly. We have simulated this interaction using ANSYS, a multiphysics software tool. Perturbations to the Whipple RPA equation due to non-uniform potential will be discussed with the intent of developing quantitative corrections to inferred parameters, such as velocity and temperature.

[1]This work was supported by NASA GSRP Grant NNG05-GL70H

12:18PM BO3.00015 Dominant unstable mode in fast electron beam plasma interaction , ANTOINE BRET, Universidad Castilla la Mancha, LAURENT GREMILLET, Commissariat Energie Atomique — The interaction of a relativistic electron beam with a plasma is a subject of relevance for the Fast Ignition Scenario as well as many astrophysical settings. It has been known for long that the system is unstable with respect to many electromagnetic instabilities such as the two-stream or the filamentation instabilities. Nevertheless, recent theoretical [1] and numerical [2] investigations accounting for the whole unstable wave vector spectrum have highlighted the role of unstable modes with vector aligned obliquely with respect to the beam. In the cold fluid limit, it was proved [3] that the relativistic beam plasma system can be governed by filamentation or oblique instabilities, depending on the beam to plasma density ratio and the beam gamma factor. We here present a full kinetic extension of this previous work accounting for relativistic Maxwell-Jüttner distributions functions for the beam and the plasma return current. We find that depending on the system parameters, filamentation, oblique and even two-stream modes can govern the system. Some of the implications are discussed. [1] A. Bret, M.-C. Firpo, C. Deutsch, PRL, 94, 115002, 2005. [2] L. Gremillet et. al., 14, 040704, 2007; M.E. Dieckman et. al., PoP, 13, 112110, 2006. [3] A. Bret, C. Deutsch, PoP, 12, 082704, 2005.

Monday, November 12, 2007 9:30AM - 12:18PM –
Session BO5 Processing, Plasma Antennas, and Electric Propulsion Rosen Centre Hotel Salon 11/12

9:30AM BO5.00001 Optimization of Extreme Ultra-Violet Emission from Laser-produced Tin Plasmas by Radiation Hydrodynamic Simulations , ATSUSHI SUNAHARA, Institute for Laser Technology Japan, AKIRA SASAKI, Japan Atomic Energy Agency, KATSUNOBU NISHIHARA, HIROFUMI UEDA, TATSUYA AOTA, SHINSUKE FUJIOKA, Institute of Laser Engineering Osaka University, MICHITERU YAMAURA, YOSHINORI SHIMADA, Institute for Laser Technology Japan, HIROAKI NISHIMURA, NORIAKI MIYANAGA, YASUKAZU IZAWA, KUNIOKI MIMA, Institute of Laser Engineering Osaka University, EUV PROJECT (JAPAN MEXT LEADING PROJECT) COLLABORATION — Extreme Ultra-Violet (EUV) emission from laser-produced tin plasmas is a candidate for the light source used in lithography of the next generation semi-conductors. In order to simulate the EUV emission from laser-produced tin plasma, we have developed the radiation hydrodynamic code "Star-1D" and "Star-2D," respectively. The calculated x-ray spectrum and EUV conversion efficiency from 1-D simulations qualitatively agree with experimental results. Calculated spectrum by 2-D code for the long scale length plasma is good agreement with experimentally measured results. Also, calculated density profiles are verified by the interferometry observations. We will show the optimized conditions and its physical interpretation for the high conversion efficiency and high power EUV light source.

9:42AM BO5.00002 Role of inert gas in the low-temperature CVD nano-crystalline diamond process. , PARESH RAY, JELANI GRIFFIN, Jackson State University — We report a systematic investigation of the effect of different inert gases on chemical vapour deposition (CVD) of nano-crystalline diamond. *In situ* optical emission measurement was employed to monitor the plasma chemistry, which possibly influences the film growth. Our result indicates that C_2 is not necessarily the key growth species for nano-crystalline diamond and we will demonstrate here that the nano-crystalline diamond film can be grown under conditions where the C_2 concentration is very small. Modelling results support the trend in number density changes for intermediate radicals with the volume percentage of argon variation for $CH_4/H_2/Ar$ plasma.

9:54AM BO5.00003 Electroluminescence of Carbon-Implanted Silicon[1] , MARCEL RISCH, MICHAEL BRADLEY, University of Saskatchewan — Silicon, being the staple semiconductor of integrated circuits and microchips, features an indirect band gap which limits its application in photonic devices. However, there is a large demand for an interface between electric circuits and optical circuits and therefore light-emitting silicon-compatible devices. A possible approach to enhance the room-temperature light properties of silicon is carbon ion implantation. We compute the absolute number of implanted ions using the Lieberman model for the ion current. Subsequently, SRIM calculations yield the concentration distribution, which has great influence on the emission spectrum. We produced Schottky diodes from the processed samples and found the most stable and efficient operation at a current density of about 2.5 A/cm^2. The observed electroluminescence, caused by compositional and structural disorder, appears orange-white to the eye. The discussed method has limitations for the quantum efficiency but shows some potential for cost-effective on-chip light emitting diodes (LED).

[1]This work is being supported by NSERC

10:06AM BO5.00004 Plasma Antenna Shielding , ESMAEIL FARSHI, IGOR ALEXEFF, TED ANDERSON, University of Tennessee, Haleakala Research and Development, Inc., UNIVERSITY OF TENNESSEE COLLABORATION, HALEAKALA RESEARCH AND DEVELOPMENT, INC. COLLABORATION — A method and calculation have been developed to protect space based antennas using plasma Frequency selective surfaces radom. The antennas we are trying to protect are currently metal but could be plasma. The scattering process of the electromagnetic waves has been investigated in a plasma antenna tube; this process is of self-important value from the point of view of studying wave propagation and absorption. When electromagnetic waves propagate in media with random inhomogeneities, there appear waves with frequencies and wave vectors which are different from the frequency and wave vector of the fundamental wave. Here, the so-called scattering process occurs. If the medium is spatially homogeneous but parameters defining its electromagnetic properties experience fluctuations, then scattering must occur on these fluctuations, the latter being random inhomogeneities. Induced charges and currents leading to radiating new scattered waves emerge in a medium under the influence of the fundamental wave, thereby initiating the appearance of scattered waves. However, within the linear approximation induced charges and currents in the homogeneous medium represent only the modification of wave propagation characteristics in a medium, as compared to vacuum, i.e., modification of the complex refractive index. The results may be generalized for physical understanding of the scattering process in plasma.

10:18AM BO5.00005 Experimental Validation of a Hydromagnetic Rankine-Hugoniot Model for Pulsed Plasma Thrusters , FLAVIO POEHLMANN, NICOLAS GASCON, MARK CAPPELLI, Stanford University — The most commonly used model for the Pulsed Plasma Thruster (PPT) is based on an electric circuit analysis, which provides only little physical insight to the mechanism by which the discharge accelerates the propellant. We present a model for the acceleration mechanism in gas-fed PPTs that is derived from early work on coaxial plasma deflagration guns[1] and is based on an analogy to chemical combustion waves. More specifically, the Rankine-Hugoniot theory for detonations and deflagrations can be extended to include magnetohydrodynamics in plasmas. Equations have been derived for the exhaust velocity and a mode transition to the so-called plasma deflagration mode that was independently observed by several researchers[1,2] can be explained based on this model. Experimental data was taken at Stanford to verify the validity of the derived equations.

[1]Cheng, D.Y., "Plasma Deflagration and the Properties of a Coaxial Plasma Deflagration Gun", Nuclear Fusion 10, 1970

[2]Woodall, D.M., Len, L.K. "Observation of current sheath transition from snowplow to deflagration" J. Appl. Phys. 57 (3), Feb 1985

10:30AM BO5.00006 High Resolution Spectral Measurements of Electrical Propulsion Plasmas , MURAT CELIK, OLEG BATISHCHEV, MANUEL MARTINEZ-SANCHEZ, Massachusetts Institute of Technology, SPACE PROPULSION LABORATORY TEAM — Among various diagnostics methods in studying the EP thrusters' plasma, emission spectroscopy provides a non-invasive, fast and economical diagnostics allowing also the ability to access hard to reach locations. This study presents the spectral measurement results of SPT (BHT-200) and TAL (MHT-9) Hall Effect thrusters and mini-Helicon (mHTX@MIT) thruster plasmas. The measurements were conducted using a 750mm focal length spectrometer with a spectral resolution of up to $\sim$0.01 nm in the UV-VIS-NIR wavelength range, 200-1000nm. For one set of the measurements, collection optics was placed on a portable optical shelf attached to the window port of the vacuum chamber. For another set of measurements the thruster plasma radiation emission was collected using a collimating lens inside the vacuum chamber and the signal was brought out of the chamber to the spectrometer by the use of UV-rated optical fibers. Accurate spectral characterization was done for Xe and Ar plasma in a broad operational range. Additionally, emission spectroscopy was used to detect line radiation due to wall erosion products in SPT, to study the effect of thruster operational parameters on the ceramic lining erosion rate, subsequently of the thruster's lifetime.

10:42AM BO5.00007 Optical Diagnostic Development of a Bismuth Hall Thruster , DAVID SCHARFE, Stanford University, MARK CAPPELLI, Stanford University — As the heaviest of all stable isotopes, bismuth is a uniquely efficient propellant option for certain plasma-based electric propulsion (E.P.) applications. In general, E.P. systems offer significant benefits over conventional chemical propulsion rockets; however, current E.P. technologies are still lacking in the efficiency and power handling required for feasible Nuclear-Electric Propulsion missions to the outer planets. One option to accommodate the requirements of such missions is an advanced bismuth-fueled Hall thruster. In preparation for development of an advanced Bi-fed Hall thruster, a laboratory-model Hall thruster has been modified to run on bismuth propellant and optical diagnostics have been developed for analyzing the bismuth plasma in the thruster exhaust. For ion velocity measurements, the Bi II 680.86 nm transition will be probed with a New Focus brand Velocity class TLB-6309 laser, and phase sensitive LIF collection will be recorded at 660.02 nm. The design of the laboratory thruster, as well as recordings of the emission and LIF signals from these transitions in the thruster, will be presented.

10:54AM BO5.00008 Plasma Flow Characterization of a mini-Helicon Thruster , NAREG SINENIAN, OLEG BATISHCHEV, MANUEL MARTINEZ-SANCHEZ, MIT, Cambridge, MA 02139, USA — We present experimental analysis of the plasma flow produced by the mini-Helicon Thruster Experiment, currently under development at the MIT Space Propulsion Laboratory. It can efficiently ionize ~1mg of Ar or N at a nominal 1kW RF power. Possible electric propulsion applications require high (~20-30km/s) exhaust velocity. Our current goal is to optimize thruster design and beam efficiency. Plasma flow is primarily measured using 2-pin Mach probes and Retarding Potential Analyzers. Several issues are addressed including RF-compensation, the effects of non-equilibrated plasma and very high energy fluxes (4MW/m^2). Measurement results from these diagnostics over the radius of the plasma jet are presented and yield an indirect measurement of the total axial thrust force. A direct measurement of the thermal component of the total axial thrust force is accomplished using a feedback controlled thrust balance, capable of measurements within a range of 0.1-20mN with a resolution of approximately .1mN. Comparison of the indirect measurements of the total axial thrust and direct measurements of the thermal component of the total axial thrust yields the magnetic component of the total thrust. The latter originates from the magnetic nozzle effect and can be varied by altering the topology of the field in the rear exhaust region.

11:06AM BO5.00009 Studies of a Pure Electron Plasma to Investigate Electron Mobility in Hall Thrusters , EMILY FOSSUM, LYON KING, Michigan Tech University — Excessive cross-field electron mobility in Hall thrusters has a negative effect on thruster efficiency and has been shown experimentally to be much larger than predicted by classical theory. An electron trapping apparatus was constructed in order to study electron dynamics in the defining electric and magnetic fields of a Hall-effect thruster in a highly controlled environment. Electrons are confined using only electric and magnetic fields without ions and dielectric walls, which are present in a typical Hall thruster. Mobility studies on a non-neutral plasma provide several advantages over a Hall thuster's quasi-neutral plasma, including a well-defined electric field and the ability to take internal electrostatic probe measurements. Cross-field electron mobility was investigated in response to magnetic and electric field strengths and background neutral density. Experimental design considerations including loading mechanisms, trapping potential, field design, and diagnostic techniques are presented along with experimental results. In this investigation, measured cross-field mobility appears to be consistent with Bohm-like mobility rather than classical mobility.

11:18AM BO5.00010 Fluctuations, Electron Transport, and Flow Shear in 2D Axial, Azimuthal (z-θ) Hybrid Hall Thruster Simulations. , EDUARDO FERNANDEZ, Eckerd College, NICOLAS GASCON, AARON KNOLL, MICHELLE SCHARFE, MARK CAPPELLI, Stanford University — Motivated by the inability of radial-axial (r-z) simulations to properly treat cross-field electron transport in Hall thrusters, a novel 2D z-θ model has been implemented. In common with many r-z descriptions, the simulation is hybrid in nature and assumes quasi-neutrality. Unlike r-z models, electron transport is not enhanced with an ad-hoc mobility coefficient; instead it is given by collisional or "classical" terms as well as "anomalous" contributions associated with azimuthal electric field fluctuations. Results indicate that anomalous transport dominates classical transport for most of the channel and near field, *except* in a strong electron flow shear region near the channel exit. The correlation between flow shear, fluctuation behavior, and electron transport will be examined, along with experimental data from the Stanford Hall Thruster. Our findings make a strong link to the turbulent transport suppression mechanism by flow shear seen in fusion devices. The scheme for combining the r-z and z-θ descriptions into an upcoming 3D hybrid model will be presented.

11:30AM BO5.00011 Introduction of Shear-Based Transport Mechanisms in Radial-Axial Hybrid Hall Thruster Simulations , MICHELLE SCHARFE, NICOLAS GASCON, DAVID SCHARFE, MARK CAPPELLI, Stanford University, EDUARDO FERNANDEZ, Eckerd College — Electron diffusion across magnetic field lines in Hall effect thrusters is experimentally observed to be higher than predicted by classical diffusion theory. Motivated by theoretical work for fusion applications and experimental measurements of Hall thrusters, numerical models for the electron transport are implemented in radial-axial hybrid simulations in order to compute the electron mobility using simulated plasma properties and fitting parameters. These models relate the cross-field transport to the imposed magnetic field distribution through shear suppression of turbulence-enhanced transport. While azimuthal waves likely enhance cross field mobility, axial shear in the electron fluid may reduce transport due to a reduction in turbulence amplitudes and modification of phase shifts between fluctuating properties. The sensitivity of the simulation results to the fitting parameters is evaluated and an examination is made of the transportability of these parameters to several Hall thruster devices.

11:42AM BO5.00012 Effects of gyrocenter shift on the retrograde motion of cathode spots and plasma transports , K.C. LEE, University of California Davis — The gyrocenter shift phenomenon explained the mechanism of radial electric field formation at the boundary of fusion devices [K. C. Lee, *Phys. Plasmas* **13**, 062505 (2006)]. The theory of gyrocenter shift is also applicable to low temperature high collisional plasmas by the generalization of the theory resulting from short mean free path comparing to gyroradius. Introducing the expanded formula of gyrocenter shift, the retrograde motion of cathode spots in the arc discharge is investigated through a model with similar parameters to an experimental study. It is found that a reversed electric field is formed in front of cathode spots when they are under magnetic field parallel to the cathode surface and this reversed electric field generates the rotation of cathode spots opposite to Amperian direction of the whole discharge. The ion drift velocity profiles calculated from the model are in agreement to the experimental results as functions of magnetic flux density and gas pressure. Also, the effect of the gyrocenter shift on the plasma transport will be discussed.

11:54AM BO5.00013 Adaptive Kinetic Model for the Ultrafast Laser Ablation Propulsion , OLEG BATISHCHEV, MIT, Cambridge, MA 02139, ALLA BATISHCHEVA, DSL Inc, Cambridge, MA 02139, JEAN-LUC CAMBIER, AFRL/PRSA, Edwards AFB, CA 93524 — Modern ultrafast femtosecond Ti:Sa lasers are capable of delivering tera-watt powers to a 1-10μm size volumes at 1-10KHz repletion rates. Though the energy per single pulse is limited to 0.01-1J, due to the unparallel energy density, the material in a focal spot ablates with high energy, instantly forming T~0.01-1MeV plasma, which corresponds to the extremely high specific impulse Isp~0.01-1Msec. Amount of the ablated material is controlled by the focal spot size. Average thrust could be controlled in the broad range by varying the atomic weight of the irradiated material and the laser repetition rate, effectively varying average power in the 10W – 10kW interval. Various practical configurations are considered. One of the possibilities is ablating micro-droplets in the strong diverging magnetic field. In this way most of the 1.5kT random energy could be directed into a half-space, thus forming an exhaust plume. The efficiency of laser energy absorption, ablated plasmas energy spectra, plume divergence, net thrust production are difficult questions to be answered. For analysis we deploy an adaptive kinetic model that solves strongly couple sets of non-linear Boltzmann-Maxwell equations. Results of the numerical simulations for a range of physical parameters – laser pulse durations, flux densities, target dimensions – will be discussed.

12:06PM BO5.00014 Micro-propulsion in space via dust - plasma thruster , GARY ZANK, KHARE AVINASH, IGPP University of California Riverside — A new scheme of micro propulsion in space i.e. the dust – plasma thruster is proposed. The scheme uses plasma thermal energy to charge externally injected sub micron sized particles and simultaneously create electric fields in the plasma which accelerates them. Particles are subsequently charge stripped and exhausted to produce electrically neutral thrust obviating the need of a charge neutralizer. For reasonable plasma and particle parameters, thrust and specific impulse over a broad range may be produced. The dependence of thrust on particle size and other plasma parameters allows for a better thruster precision. The scheme is shown to have modest power requirements. It may be realized in a simple design where there are no high voltage grids or electrodes, charge neutralizer, valves, pressurized gases etc and can operate in space or vacuum. A layout for the possible configuration is described.

Monday, November 12, 2007 9:30AM - 12:30PM –

Session BO6 Shock Waves, Plasma Expansion and Equations of State Rosen Centre Hotel Salon 5/6

9:30AM BO6.00001 Plasma expansion dynamics physics: An understanding on ion energy reduction process , DAVID RUZIC, SHAILENDRA SRIVASTAVA, KEITH THOMPSON, JOSHUA SPENCER, JOHN SPORRE, University of Illinois at Urbana-Champaign, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM — This paper studies the expanding plasma dynamics of ions produced from a 5J Z-pinch xenon light source used for EUV lithography. Ion energy reduction is essential for the successful implementation of this technology. To aid this investigation, ion energy from a z-pinch DPP plasma source is measured using an ion energy analyzer and effect of introducing a small percentage of low Z material on the ion energy and flux is investigated. Presence of low mass such as H_2 or N_2, shows a considerable reduction in total flux and in average energy. For example, Xe^+ ion flux at 5 keV are recorded as 425 $\pm$ 42 ions/cm^2.eV.pulse at 157 cm and reduced to 125 $\pm$ 12 ions/cm^2.eV.pulse when using the low mass into the system at same energy. It is also noticed that such a combination leads to decrease in sputtering without changing the EUV output. Study of the possible mechanism supporting the experimental results is numerically calculated. This computational work indicates that the observed high energies of ions are probably resulting from coulomb explosion initiated by pinch instability. It is postulated that the electrons leave first setting up an electrostatic potential which accelerates the ions. The addition of small mass actually screens the potential and decorates the ions.

9:42AM BO6.00002 Explosively Generated Plasmas in Noble Gases , C.J. BOSWELL, J.R. CARNEY, J.M. LIGHTSTONE, J. WILKINSON, G. PANGILINAN, Indian Head Division - NSWC — Non-ideal plasmas occur as a result of the stimulation of matter by strong shocks, detonation waves, or concentrated laser irradiation. Since all of these methods of generating non-ideal plasmas are already in use to address other problems, we focus on a detailed understanding of this plasma. In particular, we study the generation of this plasma by strong, ionizing guided shock waves. The shock wave in the gas is generated by an explosive located at one end of a guide tube filled with a noble gas. The detonation produces a shock wave strong enough to ionize the gas. Spectral line emission profiles, recorded with a streak emission spectroscopy system, are used to ascertain neutral and ionized gas properties. The electric and magnetic fields are measured by electrostatic probes and magnetic induction coils which permit the measurement of the temperature, density, and electric potential of the non-ideal plasma; as well as the flow of net electric charges respectively. The results demonstrate there is a mixing of the detonation products and the noble gas and that there is a pulse of electrons that travel ahead of the shock wave as it travels down the guide tube.

9:54AM BO6.00003 Numerical simulations of relativistic collisionless shocks and their radiation[1] , EDISON LIANG, JULIA SCHEEVEL, ORESTES HASTINGS, Rice University — Using 2.5D and 3D PIC codes, we simulate the collisions of relativistic electron-positron and electron-ion plasmas with and without upstream background magnetic fields. We study the growth and saturation of Weibel and other instabilities, and the diffusive acceleration of high energy particles. Using post-processing codes we also compute the in-situ radiation output of the accelerated particles. We find that in general the radiation output of Weibel mediated shocks without upstream background magnetic fields is small. Shocks mediated by strong background fields tend to radiate more efficiently due to stronger coupling between the accelerated particles and penetrated fields. The structure of e-ion shocks is complicated by electron-ion charge separation, which transfers energy from high energy electrons to ions. Particle acceleration is facililated by both charge separation and Langmuir waves in this case.

[1]work partially supported by NSF AST0406882

10:06AM BO6.00004 Two-dimensional effects on shock planarity in confined laser ablation , ERIC LOOMIS, LANL, DAMIAN SWIFT, LLNL, SHENGNIAN LUO, LANL — The ablation of solid material when illuminated with focused laser pulses is a common method for driving strong shocks into the target material and is typically treated as one-dimensional. The expansion and blow-off of the low-density, high-temperature coronal plasma has, however, non-axial flow components. In laser shock experiments, the plasma can be confined by a transparent substrate resulting in higher pressures and longer duration shock waves in the solid material for moderate laser energies. In an effort to understand the loading history and shock planarity in these targets to greater accuracy, numerical simulations have been carried out and compared to experimental velocity profiles. Two-dimensional continuum mechanics simulations have been carried out using high-temperature equations-of-state for C and Al. The laser energy is deposited into a thin layer of C or Al at the interface between a sapphire substrate and target material (Be) in a simplified manner without rigorously accounting for realistic laser-matter interactions. Variations in total energy and irradiance history on the loading are included in the study. Simulations are compared to one-dimensional radiation hydrodynamics calculations and possible improvements to the confined ablation target design are given.

10:18AM BO6.00005 Turbulent Energy Analysis Behind Normal Ionizing Shock Waves[1] , CHAVIS T. RAYNOR, JOSEPH A. JOHNSON, III, Florida A&M University, CEPAST — Using an Arc-Driven Shock Tube and Laser Induced Fluorescence, we measured the turbulent energy behind an ionizing shock wave in the presence of a weak axial magnetic field. Simultaneous density estimates were made from multiple points behind the flow. Two points measure density along the flow, while two additional points measure density across the flow. With the test gas held at constant pressure, it was determined that the turbulent energy increases linearly with increasing magnetic field strength. In contrast, the turbulent energy decreases with increasing pressure when the magnetic field is held constant. While the turbulent energy at the radial points are about the same, the strength of the turbulent energy at the axial points differ significantly from each other as well as from the radial points. This may be due to higher rates of radial diffusion towards the walls of the tube where recombination is greatest. In addition, the results of other turbulent parameters of interest will be discussed.

[1]Research supported in part by grants from the U.S. Department of Energy and the National Science Foundation.

10:30AM BO6.00006 Enhanced Signal to Noise in a Turbulent Laser Enhanced Laser Induced Plasma[1] , DELONIA WIGGINS, STEPHEN ROBERSON, JOSEPH A. JOHNSON III, Florida A&M University — A Nd-Yag pulsed laser created a plasma at a focal point in the path of a CW 1kW fiber laser beam. The CW fiber laser power increases in steps of 100W from 0W (CW fiber laser off) up to 1000W. The plasma is created in air. The optical emissions from this turbulent plasma were captured with two fiber optic cables and transmitted first to two monochrometers and ultimately to an ICCD and an oscilloscope. From the emissions of the plasma, the spectra of both the ionized and neutral lines can be captured using the ICCD. Both spectra are influenced as the power of the CW fiber laser increases. More specifically, the signal to noise ratio is systematically enhanced by the presence of the CW fiber laser beam in the path of the plasma.

[1]Research supported in part by grants from the US Army SMDC and the National Science Foundation.

10:42AM BO6.00007 Experimental determination of the Plasmon dispersion in warm-dense Beryllium.[1] , PAUL NEUMAYER, ANDREA KRITCHER, OTTO LANDEN, LLNL, HAEJA LEE, UCB, KLAUS WIDMANN, SIEGFRIED GLENZER, LLNL — The dispersion of electron plasma waves is of fundamental interest as it determines optical properties of matter. We apply x-ray Thomson scattering to measure the Plasmon dispersion in a solid-density radiatively heated beryllium plasma. A 0.6 mm diameter beryllium cylinder was isochorically heated by x-rays produced by irradiation of a silver foil with laser pulses of up to 10 kJ of energy at a wavelength of 355 nm. The plasma is probed by chlorine Lyman-alpha line radiation at 2.96 keV, produced from chlorine containing plastic foils driven by 12 kJ of laser energy. The scattered probe radiation is spectrally resolved with a high efficiency gated crystal spectrometer in forward direction giving access to the collective scattering regime. By varying the probe source location various scattering angles have been accessed. The data are compared to the current high-density statistical plasma models.

[1]Work performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

10:54AM BO6.00008 Nonequilibrium Conditions in a Shock Front , D.E. FRATANDUONO, M.A. BARRIOS, T.R. BOEHLY, D.D. MEYERHOFER, D.G. HICKS, P.M. CELLIERS, S. WILKS, LLNL, J.E. MILLER, Lockheed Martin — Recent measurements[1] on shock waves propagating in Ta_2O_5 foams showed that the shock temperature did not rise with rising pressure. An explanation is that the electrons are not in equilibrium with the ions and their temperature rise lags behind the rapidly moving shock front. Results of hydrodynamic simulations that predict such behavior and provide calculations of optical transport that explain the observations are presented. Experimental methods that could be used to further diagnose this phenomenon will be discussed. This work was supported by U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460.

[1] J. E. Miller *et al.*, "Equation-of-State Measurements in Ta_2O_5 Aerogel," submitted to the Proceedings of AIP.

11:06AM BO6.00009 High pressure melt curve and yield strength of high-density carbon[1] , J.H. EGGERT, D.G. HICKS, P.M. CELLIERS, R.F. SMITH, D.K. BRADLEY, R.S. MCWILLIAMS, G.W. COLLINS, Lawrence Livermore National Laboratory — Single and double shock temperature measurements have been used to map the melt curve of high-density carbon (diamond) from 6 to ~23 Mbars. Combining temperature and Hugoniot measurements of the high-density fluid reveal carbon melts from the diamond phase to a chemically complex, perhaps polymeric carbon phase. Ultra-high density states of carbon well off of the diamond Hugoniot have been explored using ramp wave compression techniques. These ramp wave experiments have compressed carbon to the highest pressure solid ever studied and were used to map the stress strain of carbon to a stress of ~ 10 Mbars. Finally, the yield strength of single, micro, and nano-crystalline carbon have been measured to several Mbars revealing an ultra-high, rate-dependent, and orientation dependent elastic limit ranging between 60 and 200 GPa. These measurements have been used to constrain equation of state and strength models used for designing ICF capsules with high-density carbon ablators.

[1]This work was performed under the auspices of the U. S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract No.W-7405-Eng-48.

11:18AM BO6.00010 Design for LTE EOS and opacity experiments using supersonic radiation waves[1] , T.E. TIERNEY, R.R. PETERSON, H.E. TIERNEY, Los Alamos National Laboratory — Opacity and EOS at 100-200 eV are important physical parameters in ICF experiments. We describe an experiment design that uses the supersonic propagation of hohlraum radiation in foams to isochorically heat samples. Laser and Z-pinch experiments frequently use 150 to 220-eV quasi-blackbody emission from hohlraums to drive physics experiments. A foam target encapsulated in a gold-wall cylinder is placed next to the hohlraum. The low density and opacity foam captures some hohlraum emission and generates a supersonically-propagating radiation wave. The material heated by the wave is cooler towards the high-albedo gold wall. Modeling and past measurements show that core regions of the foam have small thermal gradients. We place a small, thin sample (e.g., Al, Si, or Fe) in the thermally-uniform region. X-ray emission of tracers and the sample as well as quasi-continuum x-ray absorption will be measured using time-resolved x-ray spectroscopy. The foam's EOS can be measured to $\pm 5\%$ by blast waves with a well characterized drive. This experiment could use the OMEGA, Z-Beamlet, and/or ZR facilities to explore temperature-dependent conditions.

[1]This work is support under the auspices of the US DOE.

11:30AM BO6.00011 Wide-Range Equation of State for Ablation Studies of Titanium , DAMIAN SWIFT, THOMAS TIERNEY, ERIC LOOMIS, SHENG-NIAN LUO, Los Alamos National Laboratory, PEDRO PERALTA, Arizona State University — An equation of state (EOS) for Ti was constructed using electronic structure calculations, based on the plane-wave pseudopotential method for condensed phases and the atom-in-jellium method in other states. The EOS was adjusted to match the observed STP state using a pressure correction which extrapolates correctly to zero density. The predicted principal shock Hugoniot was in good agreement with impact-induced shock measurements. The EOS was used to simulate ablative loading experiments on rolled foils of Ti at the TRIDENT. Laser ablation generated states in the warm dense matter regime. The measured free surface velocity histories exhibited multiple wave structures indicative of plastic flow and the alpha-omega phase transition. Estimates of the flow stress and the phase transition pressure on nanosecond time scales were obtained.

11:42AM BO6.00012 *ab initio* Molecular Dynamics simulations of dense boron plasmas up to the semiclassical Thomas Fermi regime , CLEROUIN JEAN, MAZEVET STEPHANE, LAMBERT FLAVIEN, BOTTIN FRANCOIS, ZERAH GILLES, CEA/DIF Bruyeres Le Chatel France — We have performed *ab initio* simulations of dense boron along the 1 and 4 eV isotherms [1], starting from the regime where quantum mechanical effects are important to the regime where semiclassical simulations based on the Thomas Fermi approach are, by default, the only simulation method currently available. To overcome the limitations of *ab initio* simulations at high density, we have build an "all electron" norm conserving pseudopotential for boron which allows simulations up to 50 times the normal density, ρ_0. We show that, at high pressure, all electrons *ab initio* simulations are necessary to get a correct pressure, which is in close agreement with the one given by the, much faster, Thomas-Fermi molecular dynamics method [2].We further compare the Kubo-Greenwood and the Ziman formulations for the electrical conductivity.

[1] S. Mazevet et al. PRE **75**, 056404 (2007).
[2] F. Lambert et al. PRE **73**, 016403 (2006).

11:54AM BO6.00013 On and off Hugoniot measurements of aluminum using laser driven shock wave , NORIMASA OZAKI[1], Graduate School of Engineering, Osaka University, Japan, MICHEL KOENIG, LULI, Ecole Polytechnique, France, TAKATOSHI ONO, Graduate School of Engineering, Osaka University, Japan, SHINSUKE FUJIOKA, MITSUO NAKAI, Institute of Laser Engineering, Osaka University, Japan, ALESSANDRA RAVASIO, CEA, France, KEISUKE SHIGEMORI, KAZUO TANAKA, Institute of Laser Engineering, Osaka University, Japan, KUNIHIKO WAKABAYASHI, National Institute of Advanced Industrial Science and Technology (AIST), Japan, RYOSUKE KODAMA, Graduate School of Engineering, Osaka University, Japan — We performed absolute Hugoniot measurements on one of the most important metal, aluminum as a standard material. Shock and particle velocities were simultaneously measured with a side-on x-ray backlighting technique. The pressure was reached up to around 2 TPa. To know the off-Hugoniot properties, we also performed reflected shock experiments. Using copper and tantalum anvils, the Al reflected shock states were obtained in TPa pressure regime. The difference between shock reflection curves from some models is discussed.

[1]Also LULI, Ecole Polytechnique, France

12:06PM BO6.00014 The EOSTA model for opacities and EOS calculations[1] , AVRAHAM BARSHALOM, NRCN & Artep, JOSEPH OREG, Artep — The EOSTA model developed recently combines the STA and INFERNO models to calculate opacities and EOS on the same footing. The quantum treatment of the plasma continuum and the inclusion of the resulted shape resonances yield a smooth behavior of the EOS and opacity global quantities vs density and temperature. We will describe the combined model and focus on its latest improvements. In particular we have extended the use of the special representation of the relativistic virial theorem to obtain an exact differential equation for the free energy. This equation, combined with a boundary condition at the zero pressure point, serves to advance the LDA EOS results significantly. The method focuses on applicability to high temperature and high density plasmas, warm dens matter etc. but applies at low temperatures as well treating fluids and even solids. Excellent agreement is obtained with experiments covering a wide range of density and temperature. The code is now used to create EOS and opacity databases for the use of hydro-dynamical simulations.

[1]We acknowledge the encouragement of S. Obenschain, Head of the Laser Plasma Branch of the Naval Research Laboratory, and his support funded by the USDOE.

12:18PM BO6.00015 Transient Formation of Super-Explosives under High Pressure for Fast Ignition. , FRIEDWARDT WINTERBERG, University of Nevada, Reno — Dense matter, if put under high pressure, can undergo a transformation from an atomic to a molecular configuration, where the electron orbits go into lower energy levels. If the rise in pressure is very sudden, for example by a strong shock wave, the electrons change their orbits rapidly under the emission of photons, which for more than 100 megabar can reach keV energies. With the opacity of dense matter going in proportion to the square of the density, the photons can be efficiently released from the surface of the compressed matter by a rarefaction wave. The thusly produced X-ray photons can be used for the fast ignition of a thermonuclear target. Since as for thermite, the conjectured super-explosives are likely to come from the reaction between two different atoms, they should be made from a mixture of nanoparticles. The proposed mechanism may be also responsible for the large keV X-ray bursts in exploding wire arrays, which can not be explained by a simple kinetic into thermal energy conversion model.

9:30AM - 9:30AM –
Session BP8 Poster Session I: Laser and Beam Driven Acceleration/Radiation; ICF I and Laser Plasma Interactions; Shape Control, Diagnostics, Reactor Design; Astrophysical Plasmas: Experiment and Theory Rosen Centre Hotel Grand Ballroom, 9:30am - 12:30pm

BP8.00001 LASER AND BEAM DRIVEN ACCELERATION/RADIATION –

BP8.00002 Stability of monoenergetic electron beam generation in laser-driven plasma acceleration , EISUKE MIURA, SHIN-ICHI MASUDA, KAZUYOSHI KOYAMA, SUSUMU KATO, National Institute of Advanced Industrial Science and Technology (AIST) — We have so far reported the generation of monoenergetic electron beams with the energy up to 25 MeV by using a 2-5 TW, 50 fs laser pulse in laser-driven plasma acceleration.[1,2] In this paper, we will present the generation of more intense monoenergetic electron beams with higher energy. From a plasma with the electron density of 1.6 $\times 10^{19}$ cm^{-3} produced by an 8 TW, 50 fs laser pulse, monoenergetic electron beams with the energy of 40-70 MeV and considerable amount of the charge up to 70 pC have been obtained. The shot-to-shot fluctuations of the energy, energy spread and charge of the monoenergetic beams were also evaluated. To improve the quality and stability of monoenergetic electron beams obtained by self-injection scheme, the optimum conditions including the plasma density, laser pulse duration, focusing geometry, and so on are investigated. A part of this work is supported by the Budget for Nuclear Research of the MEXT.

[1] E. Miura et al., Appl. Phys. Lett. 86 251501(2005).
[2] S. Masuda et al., Phys. Plasmas 14 023103 (2007).

BP8.00003 Guiding of an intense, ultrashort laser pulse in a discharge-produced capillary plasma for electronacceleration application , TAKESHI HIGASHIGUCHI, MASAFUMI HIKIDA, HIROMITSU TERAUCHI, KUN LI, NOBORU YUGAMI, Utsunomiya University, RYOSUKE KODAMA, ILE, Osaka University — Guiding of an intense laser pulse is supported today's advanced technology such as laser wakefield acceleration, x-ray lasers, high-order-harmonic generation, and inverse Compton scattering. The laser-matter interaction length of a focused laser pulse is fundamentally limited by diffraction to the order of the Rayleigh length, and is further restricted by ionization-induced refraction. We developed a plasma waveguide for propagating intense laser pulse by use of a capillary discharge plasma. The alumina capillary had a diameter of 300 μm and a length of 10 mm. For present work, the discharge peak voltage and current were 30 kV and 500 A with a pulse width of 100 ns (FWHM), respectively. The guiding experiments used the laser pulse of the central wavelength of 800 nm from a CPA Ti:sapphire laser with a pulse width of 130 fs (FWHM). A peak intensity of the laser pulse was 1×10^{16} W/cm^2 with a spot diameter of 30 μm (FWHM) in vacuum. We demonstrated guiding of a laser pulse over length of up to 10 mm, which corresponded to 10 times the measured Rayleigh length. In addition, we also observed an electron acceleration of around 1 MeV by use of a 1- cm long gas-filled capillary waveguide at the discharge time of 150 ns.

BP8.00004 Absolute Calibration of Imaging Plate for Electron Spectrometer measuring GeV-class electrons. , NOBUHIKO NAKANII, KIMINORI KONDO, TOSHINORI YABUUCHI, KAZUKI TSUJI, KAZUO TANAKA, Institute of Laser Engineering, Osaka University, SHINSUKE SUZUKI, TAKAO ASAKA, KENICHI YANAGIDA, HIROHUMI HANAKI, Japan Synchrotron Radiation Research Institute/SPring-8, TAKASHI KOBAYASHI, KAZUHIRO MAKINO, TAKAHISA YAMANE, Fuji Film Co., Ltd — An electron spectrometer (ESM) is designed and tested to measure high-energy electrons generated from ultra-intense laser plasma interactions. In this ESM, Fuji film imaging plate (IP) is often used as a detector for avoiding the influence by a strong electromagnetic noise. In previous study, IP was calibrated for electron up to 100-MeV in order to obtained absolute number of high-energetic electron. However, in more recent laser acceleration study 1-GeV monoenergetic electron beam was produced. Therefore, we performed the absolute calibration of IP for 1-GeV electrons experimentally at SPring-8. The 1-GeV electron beam was generated from Linac for injection to the storage ring at SPring-8. In the result, it has been proved that IP has sufficient sensitivity for 1-GeV electrons and the absolute sensitivity curve for electrons up to 1 GeV was obtained.

BP8.00005 PIC Simulations and Analysis of CTR from Electron Bunches Exiting a Plasma[1]

, PAUL MULLOWNEY, DAVID BRUHWILER, CHRISTINE ROARK, Tech-X Corporation, BILL PETER, Consultant, CAMERON GEDDES, ERIC ESAREY, WIM LEEMANS, GUILLERME PLATEAU, LOASIS Group, Lawrence Berkeley National Lab — Laser wakefield accelerator (LWFA) concepts are characterized by ultra-high gradients and ultra-short bunch lengths. These short, nano-Coulomb charge bunches can radiate strongly at THz frequencies via coherent transition radiation (CTR) as they exit the plasma. Accurate modeling of the CTR in simulations is challenging even for moderately energetic bunches of 5 MeV due to constraints imposed by the formation length, L, which scales as the inverse fourth power of the angle from the bunch propagation direction to the observer's position. If the EM fields on a virtual surface near to the plasma are used to calculate the far CTR radiation field, complications arise from the self-fields of the high-charge bunch. We present results and analysis of PIC simulations of characteristic electron bunches exiting a plasma. We show that by treating the surface currents as dipole-radiators, we can compute the CTR in the far-field. These techniques are being used to study the effect of plasma density ramps and other complicating factors.

[1]Work Supported by US DOE Office of Science, High Energy Physics under grant DE-FG0204ER84097

BP8.00006 Optimization of the LBNL Laser Wakefield Accelerator as a Compact, Powerful Terahertz Source[1]

, GUILLAUME PLATEAU, NICHOLAS MATLIS, JEROEN VAN TILBORG, KEI NAKAMURA, CAMERON GEDDES, CSABA TOTH, CARL SCHROEDER, ERIC ESAREY, WIM LEEMANS, Lawrence Berkeley National Laboratory, LOASIS TEAM — At LBNL, laser wakefield accelerators (LWFA) routinely produce ultrashort electron bunches with energies up to 1 GeV [1]. As femtosecond electron bunches exit the plasma they radiate a strong burst in the terahertz range [2,3] via coherent transition radiation (CTR). Measuring the CTR properties allows non-invasive bunch-length diagnostics [4], a key to continuing rapid advance in LWFA technology. We present measurements demonstrating both the shot-to-shot stability of bunch parameters, and femtosecond synchronization between the bunch, the THz pulse, and the laser beam. In addition we present a technique for enhancing CTR generation from LWFA-produced electron beams, increasing its suitability for applications.

[1] W.P. Leemans et al., Nature Physics 2, 696 (2006);
[2] W.P. Leemans et al., PRL 91, 074802 (2003);
[3] C.B. Schroeder et al., PRE 69, 016501 (2004);
[4] J. van Tilborg et al., PRL 96, 014801 (2006)

[1]This work is supported by US DoE Office of High Energy Physics under contract DE-AC03-76SF0098 and DARPA.

BP8.00007 Controlled laser plasma wakefield acceleration of electrons via colliding pulse injection in non-collinear geometry

, CSABA TOTH, KEI NAKAMURA, CAMERON GEDDES, DMITRIY PANASENKO, GUILLAUME PLATEAU, NICHOLAS MATLIS, CARL SCHROEDER, ERIC ESAREY, WIM LEEMANS, Lawrence Berkeley National Laboratory — Colliding laser pulses [1] have been proposed as a method for controlling injection of electrons into a laser wakefield accelerator (LWFA) and hence producing high quality electron beams with energy spread below 1% and normalized emittances $<$ 1 micron. The. One pulse excites a plasma wake, and a collinear pulse following behind it collides with a counterpropagating pulse forming a beat pattern that boosts background electrons into accelerating phase. A variation of the original method uses only two laser pulses [2] which may be non-collinear. The first pulse drives the wake, and beating of the trailing edge of this pulse with the colliding pulse injects electrons. Non-collinear injection avoids optical elements on the electron beam path (avoiding emittance growth). We report on progress of non-collinear experiments at LBNL, using the Ti:Sapphire laser at the LOASIS facility of LBNL. New results indicate that the electron beam properties are affected by the presence of the second beam.

[1] E. Esarey, et al, Phys. Rev. Lett 79, 2682 (1997)
[2] G. Fubiani, Phys. Rev. E 70, 016402 (2004)

BP8.00008 Trapping and heating with colliding laser pulses[1]

, ERIC ESAREY, C.B. SCHROEDER, E. CORMIER-MICHEL, C.G.R. GEDDES, W.P. LEEMANS, LBNL, D. BRUHWILER, J.R. CARY, Tech-X — Colliding pulse injection (CPI), in which two counterpropagating laser pulses intersect in a plasma, has been proposed as a method of injecting short electron bunches into a laser wakefield accelerator.[2] When the two laser pulses overlap, the laser beat wave alters the momenta and phases of the electrons, allowing trapping in the wakefield. Recent experiments have demonstrated that CPI is capable of producing energetic electron bunches.[3] Here, theory and simulations of the beat wave injection process are presented, allowing the calculation of the bunch properties such as charge, energy, and duration. Methods for enhancing the amount of trapped charge are proposed and analyzed.

[1]Work supported by DOE grant DE-AC02-05CH11231
[2]E. Esarey et al., Phys. Rev. Lett. 79, 2682 (1997); G. Fubiani et al., Phys. Rev. E 70, 016402 (2004).
[3]J. Faure et al., Nature 444, 737 (2006).

BP8.00009 Optimization Studies of a Multi-GeV Single Stage Laser-Plasma Accelerator[1]

, G.M. TARKENTON, Institute for Advanced Physics, B.A. SHADWICK, Department of Physics and Astronomy, University of Nebraska Lincoln and Institute for Advanced Physics, C.B. SCHROEDER, E. ESAREY, LOASIS Program, LBNL — Using a self-consistent Hamiltonian model of beam transport in a background plasma[2], we consider the design of a single stage, multi-GeV plasma accelerator. In this model the beam is described by phase-space moments and the bulk plasma is taken to be a cold fluid. We present a detailed study of beam propagation in a resonant laser-wakefield accelerator with final energy gain between 5 and 10 GeV. We discuss optimization of the system with regard to energy gain and beam quality.

[1]Supported by the Institute for Advanced Physics, the University of Nebraska, and by US DoE contract DE-AC02-05CH11231
[2]B. A. Shadwick, G. M. Tarkenton and C. B. Schroeder, Bull. Am. Phys. Soc., **50**, 283 (2005).

BP8.00010 Reduced Phase-Space Models of Intense Laser-Plasma Interactions[1]

, B.A. SHADWICK, Department of Physics and Astronomy, University of Nebraska Lincoln and Institute for Advanced Physics, C.B. SCHROEDER, LOASIS Program, LBNL, G.M. TARKENTON, Institute for Advanced Physics, E. ESAREY, LOASIS Program, LBNL — We undertake a detailed comparison of a variety of reduced models — moment based descriptions: warm[2] and cold fluids as well as fixed-shape distributions: water bag, *etc.* — to direct solutions of 1-D Vlasov equation[3]. We examine the quality of the agreement between the various models as a function of both initial plasma temperature and plasma wave amplitude. We determine parameter regimes of validity for the various reduced models and comment on applicability of these models to studying laser-driven plasma accelerators.

[1]Supported by the University of Nebraska, the Institute for Advanced Physics and by US DoE contract DE-AC02-05CH11231
[2]B. A. Shadwick, G. M. Tarkenton and E. H. Esarey, Phys. Rev. Lett.**93**, 175002 (2004).
[3]B. A. Shadwick, G. M. Tarkenton, E. Esarey, and C. B. Schroeder, "Fluid and Vlasov Models of Low-Temperature, Collisionless, Relativistic Plasma Interactions," Physics of Plasmas **12**, 056710 (2005).

BP8.00011 Simulation of 1 GeV laser wakefield accelerator experiments and scaling to 10 GeV[1]

, ESTELLE CORMIER-MICHEL, C.G.R. GEDDES, W.A. ISAACS, N. STINUS, E. ESAREY, C.B. SCHROEDER, W.P. LEEMANS, LBNL, D.L. BRUHWILER, J.R. CARY, Tech-X — Recent laser-plasma accelerator experiments at LBNL have demonstrated the production of high quality 0.5 and 1.0 GeV electron beams.[2] In these experiments, the 10-40 TW laser pulse was guided in a 3 cm long capillary discharge plasma channel. Particle-In-Cell (PIC) simulations provide information not accessible from experiments on the nonlinear laser-plasma interaction that governs the accelerator internal dynamics. Simulations show that high quality electron bunches are formed by self-trapping of electrons in the wake, followed by loading of the wake by the trapped bunch, creating a bunch of electrons isolated in phase space. A narrow energy spread beam is then obtained by extracting the bunch as it outran the accelerating phase of the wake. Simulations in 2D and 3D showing details on the electron bunch, wakefield, and laser evolution are presented and compared to experimental results. Simulations on scaling these experiments to the 10 GeV level are also presented.

[1]Work supported by DOE grant DE-AC02-05CH11231.

[2]W.P. Leemans et al., Nature Physics 2, 696 (2006)

BP8.00012 Experimental Demonstration of 1 GeV Energy Gain in a Laser Wakefield Accelerator

, ANTHONY GONSALVES, KEI NAKAMURA, CSABA TOTH, CARL SHROEDER, ESTELLE CORMIER-MICHEL, WIM LEEMANS, LBNL, D. BRUHWILER, JOHN CARY, Tech-X, SIMON HOOKER, ERIC ESAREY, DMITRIY PANASENKO, LBNL, LOASIS TEAM, TECH-X TEAM, OXFORD UNIVERSITY TEAM — GeV-class electron accelerators have a broad range of uses, including synchrotron facilities, free electron lasers, and high-energy particle physics. The accelerating gradient achievable with conventional radio frequency (RF) accelerators is limited by electrical breakdown within the accelerating cavity to a few tens of MeV, so the production of energetic beams requires large, expensive accelerators. One promising technology to reduce the cost and size of these accelerators (and to push the energy frontier for high-energy physics) is the laser-wakefield accelerator (LWFA), since these devices can sustain electric fields of hundreds of GV/m. In this talk, results will be presented on GeV-class beams using an intense laser beam. Laser pulses with peak power ranging from 10-40TW were guided in gas-filled capillary discharge waveguides of length 15mm and 33mm, allowing the production of high-quality electron beams with energy up to 1 GeV. The electron beam characteristics and laser guiding, and their dependence on laser and plasma parameters will be discussed and compared to simulations.

BP8.00013 A 10 GeV laser driven accelerator: the BELLA project[1]

, W.P. LEEMANS, O. ALBERT[2], E. ESAREY, C.G.R. GEDDES, A. GONSALVES, N.H. MATLIS, K. NAKAMURA, D. PANASENKO, G.R. PLATEAU, C.B. SCHROEDER, CS. TOTH, LBNL, D.L. BRUHWILER, J.R. CARY, Tech X Corp, M. BAKEMAN, E. CORMIER-MICHEL, T. COWAN, UNR, S.M. HOOKER, Oxford University — GeV class beams have been generated from a laser driven accelerator [3]. The experiments used a cm-scale capillary discharge produced plasma channel to guide and control the process of acceleration, similar to the use of laser produced channels [4], and 40 TW laser pulses. Lower plasma density and cm-scale channel length resulted in up to 1 GeV beams, in good agreement with simulations. This forms the basis for the next milestone experiment: a 10 GeV laser driven accelerator. As part of the BELLA project at LBNL, scaling of these experiments to the 10 GeV level is now underway. We will discuss experimental plans for the implementation of a 1 m scale channel guided laser wakefield accelerator and a petawatt class laser system.

[1]Work supported by DOE grant DE-AC02-05CH11231.

[2]on sabbatical from LOA, France

[3]W.P. Leemans et al., Nature Physics **2**, 696-699 (2006); K. Nakamura et al., Phys. Plasmas **14**, 056708 (2007)

[4]C.G.R. Geddes et al., Nature **431**, 538-541 (2004)

BP8.00014 A Novel Source of Injection Electrons for a Capillary Waveguide Accelerator

, CHRIS MCGUFFEY, University of Michigan Focus Center, TAKESHI MATSUOKA, UM Focus, MICHAEL LEVIN, Hebrew University, STEPAN BULANOV, VLADIMIR CHVYKOV, GALINA KALINCHENKO, STEPHEN REED, PASCAL ROUSSEAU, VICTOR YANOVSKY, UM Focus, ARIE ZIGLER, Hebrew University, KARL KRUSHELNICK, ANATOLY MAKSIMCHUK, UM Focus — Electron beams with quasimonoenergetic and/or broadband energy spectra have been produced by focusing a high-intensity (HI)laser (30TW 35fs Ti:Sapphire) through an ablated plasma plume. The plasma is ablated from a flat material by focusing a pulsed Nd:YAG laser. The characteristics of the electron beam produced are determined by the plasma density seen by the HI pulse, which can be controlled by varying the delay between ablation and the HI pulse, the ablation material, and the distance between the laser axis and ablation surface. These electron beams are candidates for injection into a capillary plasma waveguide. Capillary waveguides offer the possibility of staging or tapering to overcome the limitation of dephasing length. This injection scheme could lead to high charge, quasimonoenergetic beams with energy on the order of 1GeV. Such beams could assume some of the roles of conventional accelerators and may offer applications in medicine, biology, and solid state physics.

BP8.00015 Analysis of Trajectories and Multi-Dimensional Phase Space Diagrams for Electrons Injected Orthogonal to Plasma Waves, and Laser and Scattered Radiation

, ARNESTO BOWMAN, RONALD WILLIAMS, Florida A&M University — Plasma waves have been shown to be capable of accelerating electrons over very short distances beyond what is capable by conventional accelerators. The orthogonal injection of electrons is being explored as a diagnostic to infer the amplitude of the large accelerating electric fields associated with plasma wave accelerators. The orthogonal geometry suggests that the particles have trajectories in three dimensions, and we will describe simulation studies of these trajectories. We will also discuss the results of our studies of the multi-dimensional phase space diagrams of electron dynamics in the lab and wave frames. We also describe the changes to the trajectories and diagrams that occur when transverse laser fields and scattered laser radiation fields are included with the longitudinal plasma wave fields. It is necessary for electron beams used for plasma wave diagnostics to have very small transverse emittance. We describe our studies of scanning and photographic methods for measuring beam emittance in our experiments. We are attempting to characterize our thermionic cathode and to compare the predicted emittance, based on power input, with the emittance measured using our apparatus.

BP8.00016 Beam loading in the blowout regime of laser/plasma wakefield acceleration.[1]

, MICHAIL TZOUFRAS, WEI LU, CHENGKUN HUANG, FRANK TSUNG, WARREN MORI, UCLA, JORGE VIEIRA, RICARDO FONSECA, LUIS SILVA, IST (Portugal) — The amount of charge, the final energy, and the quality of the charged particle beam that is generated from a plasma-based accelerator depends on how the charge is loaded into the wake. In recent experiments the wakes are created by either the radiation pressure of the laser or the space-charge force of the electron beam expelling the plasma electrons outward. We present a theory for beam loading valid for such nonlinear multi-dimensional wakes. We start from the equation for the blowout radius derived by Lu et al. [1]. Analytical solutions are found for this equation when the wake is loaded by flat-top or trapezoidal electron beams. As a result expressions for the accelerating field, the shape of the bubble and the amount of charge are obtained. These are compared to those predicted by the linear theory of Katsouleas et al. [2]. We also discuss the optimum current profile to minimize the final energy spread while maximizing the mean energy and the number of particles. [1] W. Lu et al, Phys. Rev. Lett. 96, 165002 (2006). [2] T. Katsouleas et al, Particle Accelerators, 1987, Vol. 22, pp. 81-99.

[1]Work supported by: DE-FG03-92ER40727, DE-FG52-06NA26195, DE-FC02-01ER41179, DE-FG02-03ER54721, NSF-Phy-0321345.

BP8.00017 Simulation and calculation of particle trapping using a quasistatic simulation code[1]

, SEPEHR MORSHED, JOHN PALASTRO, THOMAS ANTONSEN, IREAP, University of Maryland, CHENGKUN HUANG, WARREN MORI, UCLA — In LWFA schemes the laser pulse must propagate several centimeters and maintain its coherence over this distance, which corresponds to many Rayleigh lengths. These Wakefields and their effect on the laser can be simulated in quasistatic approximation [1, 2]. In this approximation the assumption is that the driver (laser) does not change shape during the time it takes for it to pass by a plasma particle. As a result the particles that are trapped and moving with near-luminal velocity can not be treated with this approximation. Here we have modified the 2D code WAKE with an alternate algorithm so that when a plasma particle gains sufficient energy from wakefields it becomes trapped to satisfy the trapping conditions. Similar implementations have been made in the 3D cod QUICKPIC [2]. We also have done simulation and comparison of results for centimeter scale GeV electron accelerator experiments from LBL [3] with WAKE. These changes in WAKE will give users a tool that can be used on a desk top machine to simulate GeV acceleration. [1] P. Mora and T. M. Antonsen Jr., Phys Plasma 4, 217 (1997) [2] C. Huang et al. Comp Phys. 217 (2006) [3] W. P. Leemans et al. Nature Phys 2, 696 (2006) Letters

[1]Work supported by DOE.

BP8.00018 Design and simulation of a single 100GeV stage Laser Wakefield Accelerator.[1]

, WEI LU, MICHAIL TZOUFRAS, CHENGKUN HUANG, FRANK TSUNG, WARREN MORI, UCLA, JORGE VIEIRA, RICARDO FONSECA, LUIS SILVA, IST (Portugal), JAMES COOLEY, THOMAS ANTONSEN, U. Maryland — The design of a laser wakefield accelerator involves understanding and control of various plasma physics phenomena related to the laser evolution, the response of the plasma medium and its effect on the accelerating particles. Within the framework developed by W. Lu et al. [1] we study these phenomena in the weakly nonlinear blowout regime, where the laser power is similar to the critical power for self-focusing. High quality electron beams can be accelerated in this regime in a single stage with average gradient 3.6GeV/m to reach 100 GeV. Full and reduced particle-in-cell simulations are presented to illuminate the physics and verify the applicability of the design.

[1] W. Lu et al, "Generating multi-GeV electron bunches using single stage laser wakefield acceleration in a 3D nonlinear regime," Phys. Rev. ST Accel. Beams 10, 061301 (2007)

[1]Work supported by: DE-FG03-92ER40727, DE-FG52-06NA26195, DE-FC02-01ER41179, DE-FG02-03ER54721, NSF-Phy-0321345.

BP8.00019 Detailed numerical modeling of electron injection in the Laser Wakefield Accelerator: Particle Tracking Diagnostics in PIC codes

, R.A. FONSECA, ISCTE - Lisbon, IST - Lisbon, L. GARGATÉ, S.F. MARTINS, F. PEANO, J. VIEIRA, L.O. SILVA, IST - Lisbon, W.B. MORI, UCLA — The field of laser plasma acceleration has witnessed significant development over recent years, with experimental demonstrations of the production of quasi mono-energetic electron bunches, with charges of $\sim$ 50 pC and energies of up to 1 GeV [1]. Fully relativistic PIC codes, such as OSIRIS [2] are the best tools for modeling these problems, but sophisticated visualization and data analysis routines [3] are required to extract physical meaning from the large volumes of data produced. We report on the new particle tracking diagnostics being added into the OSIRIS framework and its application to this problem, specifically targeting self-injection. Details on the tracking algorithm implementation and post processing routines are given. Simulation results from laser wakefield accelerator scenarios will be presented, with detailed analysis of the self injection of the electron bunches.

[1] W.P. Leemans et al, Nature Phys. 2 696 (2006)
[2] R. A. Fonseca et al., LNCS 2331, 342, (2002)
[3] R. A. Fonseca, Proceedings of ISSS-7, (2005)

BP8.00020 Self-Steepening of intense laser pulses in plasmas

, JORGE VIEIRA, FREDERICO FIÚZA, LUIS SILVA, GoLP/Centro de Física dos Plasmas, Instituto Superior Técnico — In state-of-the-art Laser Wake Field Acceleration (LWFA) experiments [1], the self-modulations of the laser pulse (both transverse and longitudinal) play an important role in the enhancement of the plasma wave, which can trap, accelerate and lead to quasi-mono-energetic electron beams. In this work, the self-steepening of intense laser pulses is studied analytically resorting to the photon-kinetic theory [2]. Rates for the growth of self-steepening in the early laser propagation are provided in the long and short pulse limits, and in the weakly and ultra relativistic regimes. Thresholds for the on-set, maximum and minimum growth of self-steepening are determined. We find very good agreement between the analytical model and one-dimensional PIC simulations with OSIRIS [3]. Implications of our results to state-of-the-art LWFA experiments are discussed.

[1] W.P. Leemans et al Nat. Phys., 2 (10), 696-699 (2006)
[2] L.O. Silva et al, IEEE TPS 28 (4) 1128-1134 (2000)
[3] R. A. Fonseca et al, LNCS 2331, 342-351, (Springer, Heidelberg, 2002).

BP8.00021 Creation of a multi-centimeter low density plasma channel using high magnetic fields[1]

, B. POLLOCK, UC San Diego, D.H. FROULA, P. DAVIS, LLNL, J.S. ROSS, UC San Diego, A. COLLETTE, UC Los Angeles, L. DIVOL, P. MICHEL, N. MEEZAN, Lawrence Livermore National Laboratory, G. TYNAN, UC San Diego, S.H. GLENZER, Lawrence Livermore National Laboratory — We will present experimental results that show the formation of a laser produced plasma channel when applying a large external magnetic field. This channel is suitable for guiding laser beams and is directly applicable to wakefield acceleration and short pulse laser amplification. This is accomplished by applying a technique that has been established at the Jupiter Laser Facility; an external magnetic field is used to prevent radial heat transport [D. H. Froula *et.al.*, Phys. Rev. Lett. 98, 135001 (2007)] resulting in an increased temperature gradient. Temporally resolved Thomson-scattering measurements of the electron temperature profile in large magnetic fields show that the heat front, transverse to a high-power laser beam, is slowed resulting in extremely strong local heating. This strong local heating produces a density channel that is measured with interferometry for densities between 10^{17} cm^{-3} to 10^{19} cm^{-3}.

[1]This work was partially supported by LDRD 06-ERD-056 and performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

BP8.00022 Electron Acceleration by a Tightly Focused Laser Pulse

, K.I. POPOV, University of Alberta, Edmonton, Alberta, Canada, V. YU. BYCHENKOV, P.N. Lebedev Physics Institute. Moscow, Russia, W. ROZMUS, R. SYDORA, University of Alberta, Edmonton, Alberta, Canada — By using the test particle approach we have studied electron vacuum acceleration including nonadiabatic effects and synchronized trajectories which correspond to particles experiencing constant phase of electromagnetic fields and subluminous phase velocity. After the averaging over the laser field phase, the energy and emission angle distributions versus the electron positions in the focal region have been obtained. The most effective acceleration was found for electrons placed at laser beam axes at the distance comparable to the Rayleigh length before the best focus position. The correlations between electron energies and the emission angles were studied. We also obtained the dependence of the maximum electron energy on the focal spot size. Results of test particle studies guided 3D particle-in-cell simulations with thin foil targets for the best conditions for electron acceleration in the Coulomb explosion regime.

BP8.00023 Petawatt laser-driven wakefield accelerator: All-optical electron injection via collision of laser pulses and radiation cooling of accelerated electron bunches.[1] , SERGUEI KALMYKOV, YOAV AVITZOUR, S. AUSTIN YI, GENNADY SHVETS, IFS, The University of Texas at Austin — We explore an electron injection into the laser wakefield accelerator (LWFA) using nearly head-on collision of the petawatt ultrashort ($\sim$30 fs) laser pulse (driver) with a low- amplitude laser (seed) beam of the same duration and polarization. To eliminate the threat to the main laser amplifier we consider two options: (i) a frequency-shifted seed and (ii) a seed pulse propagating at a small angle to the axis. We show that the emission of synchrotron radiation due to betatron oscillations of trapped and accelerated electrons results in significant transverse cooling of quasi- monoenergetic accelerated electrons (with energies above 1 GeV). At the same time, the energy losses due to the synchrotron emission preserve the final energy spread of the electron beam. The "dark current" due to the electron trapping in multiple wake buckets and the effect of beam loading (wake destruction at the instant of beams collision) are discussed.

[1]This work is partly supported by U.S. D.o.E. under Contracts No. DE-FG02-04ER54763, DE-FG02-04ER41321, DE-FG02-07ER54945, and by the NSF grant PHY-0114336 administered by the FOCUS Center at the University of Michigan, Ann Arbor.

BP8.00024 Relativistic self-focusing of multi-color laser pulses in plasmas.[1] , G. SHVETS, S. AUSTIN YI, S. KALMYKOV, IFS, The University of Texas at Austin — An intense laser beam (with a power less than critical for the relativistic self-focusing) can be guided in plasmas with the help of an additional small-amplitude co-propagating beam (few- percent of the main beam energy). The guiding is effective if the beams' frequency detuning is slightly below the electron plasma frequency. The enhanced guiding is caused mostly by the near-resonantly driven 3D electron density perturbation (plasma beatwave). Another intriguing effect of the nonlinear guiding of ultra-short ($< 1/\omega_p$) radiation spikes is observed during the later stage of laser propagation. Periodic train of such spikes is self-consistently generated via electromagnetic cascading [S. Kalmykov and G. Shvets, Phys. Rev. Lett. **94** 235001 (2005); Phys. Rev. E **73** 046403 (2006)]. The guiding effect of the plasma wave partly suppresses the diffraction and results in a multi-centimeter guided propagation of the intense pulse train. Acceleration of externally injected electrons in the cascade-driven wake is quasi-monoenergetic and is characterized by low normalized transverse emittance and near-GeV energy gain.

[1]This work is partly supported by U.S. D.o.E. under Contracts No. DE-FG02-04ER54763, DE-FG02-04ER41321, DE-FG02-07ER54945, and by the NSF grant PHY-0114336 administered by the FOCUS Center at the University of Michigan, Ann Arbor.

BP8.00025 Direct ion acceleration with variable-frequency lasers , FABIO PEANO, JORGE VIEIRA, RICARDO FONSECA, LUIS SILVA, GoLP/CFP, Instituto Superior Tecnico, Lisboa, Portugal, GIANNI COPPA, ROBERTA MULAS, Politecnico di Torino, Italy — Laser-based ion acceleration commonly relies on indirect schemes, in which the ions are accelerated by the space-charge field in laser-irradiated solid targets, either via plasma-expansion processes [1], or resorting to electrostatic shock structures [2]. Here, we propose the production of monoergetic ion beams via direct acceleration by the laser field (in vacuum or in tenuous plasmas) [3]. The method exploits two counterpropagating lasers with variable frequency to drive a beat-wave structure with variable phase velocity: the ions are trapped in the beat wave and accelerated to high energies. The physical mechanism is described with a 1D theory, providing the general conditions for trapping and scaling laws for the relevant ion-beam features. The validity and the robustness of the method are confirmed by 2D PIC simulations with OSIRIS [4].

[1] J. Fuchs *et al.*, Nature Phys. **2**, 48 (2006); L. Robson *et al.*, Nature Phys. **3**, 58 (2007); B.M. Hegelich *et al.*, Nature **439**, 441 (2006).
[2] L.O. Silva *et al.*, Phys. Rev. Lett. **92**, 015002 (2004).
[3] F. Peano *et al.*, submitted for publication (2007).
[4] R. A. Fonseca *et al.*, Lect. Notes Comp. Sci. **2331**, 342 (Springer-Verlag, Heidelberg, 2002).

BP8.00026 On The Possibility of Accelerating Positron on an Electron Wake , XIAODONG WANG, TOM KATOULEAS, PATRIC MUGGLI, USC, RASMUS ISCHEBECK, SLAC — A new approach for positron acceleration in non-linear plasma wakefields driven by electron beams is presented. Positrons can be produced by colliding an electron beam with a thin foil target embedded in the plasma. Integration of positron production and acceleration in one stage is realized by a single relativistic, intense electron beam. Simulations with the parameters of the proposed SABER facility at SLAC suggest that this concept could be tested there.

BP8.00027 Study of relative ion acceleration efficiencies from laser-solid interactions[1] , CHRISTOPHER MURPHY, ENAM CHOWDHURY, JOHN MORRISON, LINN VAN WOERKOM, The Ohio State University, KARL KRUSHELNICK, University of Michigan, RICHARD FREEMAN, The Ohio State University — The production of high-energy proton and ion beams has important applications in many areas of science including inertial fusion energy, laboratory astrophysics and compact particle sources for use in radiography and medical oncology. Utilizing laser plasma interactions (LPI) for such a source is garnering support from the various communities due to its potential to be compact and mobile. Recent studies have suggested that while increasing the laser intensity in LPIs is important for high energy ion production, moving to ultrashort (sub-picosecond) laser pulses may not be as effective as increasing the energy. An experimental study of this hypothesis will be presented, comparing the ion beam spectrum, charge and spatial quality using both magnetic spectrometers and film stacks.

[1]This work was supported by the Air Force Office of Scientific Research grant number FA9550-07-1-0088

BP8.00028 A high gradient plasma wakefield accelerator using two subpicosecond electron bunches , EFTHYMIOS KALLOS, PATRIC MUGGLI, TOM KATSOULEAS, USC, KARL KUSCHE, IGOR PAVLISHIN, IGOR POGORELSKY, DANIIL STOLYAROV, VITALY YAKIMENKO, BNL, WAYNE KIMURA, STI Optronics, Inc — A high gradient plasma wakefield accelerator was tested at the Accelerator Test Facility of Brookhaven National Lab. Two $\sim$100fs electron bunches with total charge of 0.5nC separated by $\sim$500fs were fed into a 6mm long high density (1e14/cc to 1e17/cc) plasma generated by an ablative capillary discharge. The drive bunch created a $\sim$300MV/m wakefield that was sampled by the short witness bunch. The relative position of the witness bunch with respect to the drive bunch wakefield could be adjusted by varying the plasma density, thus allowing controllable energy loss or energy gain with small energy spread. The experimentally observed energy shifts are in good agreement with 2D model predictions.

BP8.00029 Beam head erosion in self-ionized plasma wakefield accelerators , MIAOMIAO ZHOU, CHRIS CLAYTON, CHENGKUN HUANG, CHAN JOSHI, WEI LU, KEN MARSH, WARREN MORI, UCLA, TOM KATSOULEAS, PATRIC MUGGLI, ERDEM OZ, USC, MELISSA BERRY, IAN BLUMENFELD, FRANZ-JOSEF DECKER, MARK HOGAN, RASMUS ISCHEBECK, RICHARD IVERSON, NEIL KIRBY, ROBERT SIEMMAN, DIETER WALZ, SLAC — In the recent plasma wakefield accelerator experiments at SLAC, the energy of the particles in the tail of the 42 GeV electron beam were doubled in less than one meter [1]. Simulations suggest that the acceleration length was limited by a new phenomenon – beam head erosion in self-ionized plasmas. In vacuum, a particle beam expands transversely in a distance given by beta*. In the blowout regime of a plasma wakefield [2], the majority of the beam is focused by the ion channel, while the beam head slowly spreads since it takes a finite time for the ion channel to form. Beam/plasma parameter scan in a large range using simulations shows that in self-ionized plasmas, the head spreading is exacerbated compared to that in pre-ionized plasmas, causing the ionization front to move backward (erode). A theoretical analysis on the erosion rate dependence on beam/plasma parameters and its implications on future afterburner relevant experiments will be provided. [1] I. Blumenfeld et al., Nature 445, 741(2007) [2] J. B. Rosenzweig et al., Phys. Rev. A 44, R6189 (1991)

BP8.00030 Spectral Modulation of Self-Guided Laser Pulses , ARTHUR PAK, JOE RALPH, KEN MARSH, CHENGKUN HUANG, FANG FANG, CHRIS CLAYTON, CHAN JOSHI, University of California Los Angeles — In this paper the experimental results of spectral modulation of a self-guided laser pulse in an underdense plasma will be presented. Experiments were conducted using an ultrashort laser pulse ($\sim$50 fs) generated from the UCLA Ti:Sapphire laser system capable of delivering up to 10 TW of power. A gas jet was used to create a dense column of helium gas which the laser pulse ionized and self-guided through. By varying the laser pulse width, laser energy, gas jet density and gas jet length, different physical mechanisms of self-guiding were explored. In these experiments the guided laser pulse was spectrally and spatially resolved using a .25 m imaging spectrograph with 1.2 nm spectral resolution and 13 μm spatial resolution. Evidence of photon acceleration / deceleration due to the laser pulse interacting with density oscillations of a plasma wakefield will be presented and compared to simulation results. Additionally using the imaging spectrograph the percentage of the laser energy that was self-guided was determined.

BP8.00031 3D PIC Simulations of Laser Produced Plasma Expansion with Large Ion Larmor Radius[1] , MASANORI NUNAMI, AKIRA TAKATA, KATSUNOBU NISHIHARA, Institute of Laser Engineering, Osaka University, CSN TEAM — We have investigated expansion of laser produced cluster plasma in a strong magnetic field using 3D PIC simulation. Since initial electron pressure of laser heated cluster is much higher than magnetic pressure, electrons first expand and ions are accelerated outward due to electric field generated by expanding electrons. In the expansion of cluster plasma in magnetic field, ion Larmor radius is much larger than the initial cluster size, while electron Larmor radius is much smaller than the cluster size, namely, Re << Ro << Ri, where Re(i) is Larmor radius of electron (ion) and Ro is the initial cluster size. Accelerated ions expand up to about their Larmor diameter. Therefore magnetized electron surface separates from ion surface. The surface of magnetized electrons is unstable for the flute type instability mainly due to the inward-directed electric field created by streaming ions with large Larmor radius [1]. However we found that ion surface is relatively stable, which is different from previous works.

[1] B. H. Ripin et al, Phys. Fluids B5, 3491 (1993).

[1]A part of this work was performed under the auspices of MEXT under contract subject "Leading project for EUV lithography source development."

BP8.00032 ICF I AND LASER PLASMA INTERACTIONS —

BP8.00033 Update on Specifications for LMJ Ignition Targets , GIORLA JEAN, CEA, CHERFILS CATHERINE, GALMICHE DIDIER, GAUTHIER PASCAL, LAFFITE STEPHANE, MASSE LAURENT, POGGI FRANCOISE, QUACH ROBERT, SEYTOR PATRICIA — The Laser Mégajoule (LMJ) facility will deliver up to 1.40 MJ of 0.35 μm light in 160 beams in a first step. The targets for the first ignition experiments rely on indirect drive and use plastic capsules doped with germanium. The target fabrication specifications are the result of an extensive robustness study where all fabrication, laser and experimental errors are taken into account. This study is complete for the 'baseline' target A1040 designed for 240 beams and is in progress for lower laser energy targets. The target dispersions are regrouped into 1D errors, which keep the implosion spherical, and 3D errors, which induce a deformation of the DT shell. The 3D robustness is expressed in terms of non linear deformation at peak velocity and compared to the deformation threshold obtained with 2D simulations. We have performed an experimental design method based on 2000 1D-simulations, which gives the fusion energy as a function of the 22 1D-parameters and allows us to estimate the 1D-margin, as a function of DT aging and DT gas density for a given temperature law.

BP8.00034 NIF ignition target requirements, margins, and uncertainties[1] , STEVEN HAAN, JAY SALMONSON, DANIEL CLARK, DEBRA CALLAHAN, BRUCE HAMMEL, LAURANCE SUTER, JOHN EDWARDS, JOHN LINDL, Lawrence Livermore National Laboratory — We describe simulations of NIF ignition targets, concentrating on a point design target that uses 1.3 MJ to drive a hohlraum to 285eV. The point design capsule has 5 layers of varying Cu dopant to minimize RT instability growth. A set of requirements has been developed that describes all aspects of the target, its fabrication and fielding, the laser pulse, and the features of the pre-ignition experiments that are needed to finalize the design. We describe a model that characterizes the margin of the target as a function of the input parameters and uncertainties. The model has been normalized to 1D, 2D, and 3D simulations. It has been used to define and update the point design, to quantify the impact of each requirement, and to ensure that the requirements are optimally defined. The model can be used to project the probability of ignition, as shot-to-shot variations and more globally given systematic errors. There are several backup targets that are being kept active, including other drive temperatures from 270 to 300eV, CH ablators, and high density C ablators. The relative performance, and specific pertinent issues, regarding these targets are described.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of Californial Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

BP8.00035 Plans for and Progress Towards and Inertial Confinement Fusion Code from the Crestone Project , JOHN WOHLBIER, Los Alamos National Laboratory, CHARLES WINGATE, THOMAS MASSER, GREGORY BOWERS, MICHAEL SORICE, LANL, CRESTONE PROJECT CODE TEAM TEAM — The Crestone Project at Los Alamos National Laboratory has recently released *cassio*, a code for use in simulating Inertial Confinement Fusion. The initial release of *cassio* included a radiation hydrodynamics capability, a 3T plasma physics model [1], and a laser ray tracing capability [2], all implemented on an Eulerian AMR mesh. Future enhancements to the code will include higher order radiation transport, improved plasma models (e.g., electron, ion, and radiation temperatures per material in mixed cells), charged particle transport, thermonuclear burn, and conformal AMR meshes to ensure symmetric capsule implosions. In this paper we detail the existing models in *cassio* and lay out our plans for the future code enhancements.

[1] J.G. Wohlbier, Los Alamos National Laboratory Report, LAUR pending, (2007).
[2] M. Sorice, Los Alamos National Laboratory Report, LAUR pending, (2007).

BP8.00036 Colliding plasmas in laser irradiated cavities studied with soft x-ray interferometry[1] , JORGE FILEVICH, Colorado State University, MIKE PURVIS, JONATHAN GRAVA, MARIO C. MARCONI, JORGE ROCCA, CSU, JAMES DUNN, STEPHEN J. MOON, LLNL, VYACHESLAV SHLYAPTSEV, UC Davis, ELA JANKOWSKA, WUT, NSF ERC FOR EXTREME ULTRAVIOLET SCIENCE AND TECHNOLOGY, COLORADO STATE UNIVERSITY COLLABORATION, LAWRENCE LIVERMORE NATIONAL LABORATORY COLLABORATION, UNIVERSITY OF CALIFORNIA DAVIS AT LIVERMORE COLLABORATION, WROCLAW UNIVERSITY OF TECHNOLOGY, WROCLAW, POLAND COLLABORATION — Electron density maps of dense converging plasmas created by laser irradiation of semi-cylindrical and V–shaped targets at $I = 1 \times 10^{12}$ W/cm^2 were obtained with soft x-ray laser interferometry ($\lambda = 46.9$ nm). In the case of the cylinders, the plasma expands off the target surface converging in a focal region, creating a concentrated plasma where the electron density build-up exceeds 1×10^{20} cm^{-3}. The plasma in the V-shaped targets concentrates along the symmetry plane of the target where collisions redirect the plasma forming, early on in the evolution, a narrow jet-like plasma. The measurements were compared with simulations obtained using the code HYDRA.

[1]Work sponsored by the NNSA-SSAA program through DOE Grant # DE-FG52-060NA26152 and the U.S. DOE Lawrence Livermore National Laboratory through ILSA, under contract No. W-7405-Eng-48.

BP8.00037 Progress in High-Energy-Density Plasma Jet Theoretical Research[1] , CHIPING CHEN, JING ZHOU, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139 — A self-consistent phase-space moment description is developed for high-energy-density plasma jets. The phase-space moment theory is the truncated moment average of the kinetic equation. Using the phase-space moment theory, the root-mean-square (rms) envelope equations, which describe the orientation and size of the plasma jet, are derived for high-energy-density plasma jets. The envelope equations are demonstrated to agree with the virial theorem. To study the role of magnetic field helicity in plasma jet compression, a simplified model of a plasma jet is employed, and a complete set of equations governing the plasma jet is derived. The characteristic distance over which the compression occurs is calculated.

[1]Research supported by Department of Energy, Office of Fusion Energy Science, Grant No. DE-FG02-05ER54836.

BP8.00038 Acceleration of thin flyer foils with a 1 MA pulsed power device for shock-wave experiments in clumpy foam targets[1] , STEPHAN NEFF, JESSICA FORD, DAVID MARTINEZ, CHRISTOPHER PLECHATY, SANDRA WRIGHT, RADU PRESURA, University of Nevada, Reno — The dynamics of shock waves in clumpy media are important for understanding many astrophysical processes, including the triggering of star formation in interstellar gas clouds by passing shock waves. This phenomena can be studied in the laboratory by launching a flyer plate into a low density foam with clumps. Low density foams offer the advantage of relative low sound speeds (a few hundred meters per second) compared to normal solids, thus reducing the flyer speed required to create shock waves. In first experiments aluminum foils with thicknesses between 20 micrometer and 130 micrometer were accelerated to speeds up to 2.3 km/s. In addition, the impact of the flyers on plexiglas targets was studied. Additional measurements will focus on optimizing the flyer properties (thicker flyers, higher velocities) and on characterizing the flyer in more detail (temperature of the flyer and plasma ablation from the flyer). The results of these measurements will be used to design an experiment studying the dynamics of shock waves in clumpy foams, using the 100 TW laser system Leopard for back-lighting the foam target.

[1]DOE NNSA Grant DE-FC52-06NA27616

BP8.00039 Impact of High-Z Coatings on the Ablation Pressure of Laser Driven Targets. , ANDREW MOSTOVYCH, Enterprise Sciences, Inc., JAECHUL OH, ANDREW SCHMITT, JAMES WEAVER, US Naval Research Laboratory — Recent hydrodynamic experiments [1] with planar high-Z coated targets at the Naval Research Laboratory and spherical implosion experiments with high-Z coated shell targets [2] at the Omega facility all show significant improvement in target stability as a result of the high-Z coatings. For better understanding of the hydrodynamic processes it is important to know the changes in ablation pressure as a result of the high-Z layers. Using the Nike Laser, we have conducted new experiments to measure the change in shock speed of planar CH targets that are irradiated with and without the presence of a 200 Ang. gold high-Z coating. The evolution of shock propagation inside the targets is diagnosed with VISAR probing while average shock velocities are also measured by shock breakout detection from the stepped rear surface of the targets. We find that the high-Z layers produce a time dependent ablation pressure which is detected via the observation of non-steady shocks in the targets. Experimental results and comparisons to hydrodynamic simulations will be presented. Work supported by U. S. Department of Energy.
[1] S.P. Obenschain et al., Phys. Plasmas 9, 2234 (2002).
[2] A.N. Mostovych et al., APS Abstracts DPPFO3002M, (2005).

BP8.00040 Transverse modulation instability of white light in plasmas , L.O. SILVA, IST, Lisbon, R. BINGHAM, RAL, UK, B. BRANDAO, IST, Lisbon, J. SANTOS, U. Cambridge, UK — The transverse modulation, or filamentation, instability of intense radiation with arbitrary spatial coherence in plasmas is analyzed with generalized photon kinetic theory [1,2], which includes both forward and backward scattered radiation. The instability threshold as well as the growth rate dependence with the laser bandwidth are determined. The analytical results are compared with numerical solutions of the generalized dispersion relation and with full PIC simulations. Consequences of white light driven parametric instabilities in ICF and fast ignition scenarios are also discussed.
[1] J. P. Santos, and L. O. Silva, Journal of Mathematical Physics 46, 102901 (2005)
[2] J. E. Santos, L. O. Silva, R. Bingham, Physical Review Letters 98, 235001 (2007), also arXiv:0704.2831 (http://arxiv.org/abs/0704.2831)

BP8.00041 Measurements of the energy flow and plasma dynamics in a laboratory analogue of N-waves in the solar atmosphere , M. TAYLOR, J. FOSTER, P. GRAHAM, A. MOORE, AWE Aldermaston, UK, S. MACLAREN, P. YOUNG, G. GLENDINNING, A. REIGHARD, C. SORCE, LLNL Livermore, USA, C. BACK, J. HUND, B. BLUE, GA, San Diego, USA — Density perturbations in the solar atmosphere are coupled to the X-ray radiation field and so their evolution is difficult to simulate. To assess the fidelity of our current modeling capabilities, a series of experiments have been performed on the LLE OMEGA laser. These used a hohlraum to drive X-rays through a tantalum aerogel disk containing a machined slot. The dynamic evolution of this system is diagnosed with several complementary methods. The energy flow was measured using both direct flux and hohlraum calorimetry, which are compared to assess the best technique. 2D X-ray self-emission images of the data reveal structure in the radiation front seeded from localized spatial perturbations in the foam areal density. Point projection radiography down the axis of the hohlraum was utilized to determine the associated density structures, including complex irregular flows.

BP8.00042 Nonlocal heat transport using optically-smoothed lasers in direct-drive ICF[1] , MICHAEL KESKINEN, DENIS COLOMBANT, ANDREW SCHMITT, Plasma Physics Division, Naval Research Laboratory, WALLY MANHEIMER, RSI — Electron thermal conduction is important in direct-drive inertial confinement fusion. Since it is responsible for transporting laser energy absorbed near the critical surface into the overdense region, it can directly affect ablation and implosion dynamics. For high laser intensities, nonlocal transport models need to be used to accurately calculate populations of fast electrons which may lead to target preheat. Optically smoothed laser radiation changes on a coherence time scale. For these reasons we are developing a Fokker-Planck (FP) code which is coupled to an electromagnetic full-wave Maxwell solver. We present results from this coupled model for a range of laser intensities, using different collisional operators, e.g., Krook, and radiation transport effects for high-Z targets.

[1]Work supported by U.S. Department of Energy.

BP8.00043 Plasma Heating and Fusion Neutron Production in Collisions of Planar CD Foils at Velocities Above 400 km/s.[1] , A.L. VELIKOVICH, S.T. ZALESAK, A.J. SCHMITT, Plasma Physics Division, Naval Research Laboratory, Washington, DC, N. METZLER, SAIC and Physics Department, NRCN, Israel , M. MURAKAMI, T. SAKAIYA, K. SHIGEMORI, H. SHIRAGA, S. FUJIOKA, T. WATARI, H. SAITO, H. AZECHI, Institute of Laser Engineering, Osaka University — Interest in experiments on colliding planar CD foils has recently been stimulated by (a) the Impact Fast Ignition approach to laser fusion [1], which involves the collision of a shell accelerated to ∼1000 km/s with high-density DT fuel, and (b) the approach to a high-repetition rate ignition facility based on direct drive with the KrF laser and a very high implosion velocity, ∼450 km/s, to reduce the ignition threshold and increase gain [2]. Studies of planar foil collisions at hyper-velocities help test feasibility of both concepts. We present the results of modeling the recent experiments at ILE, where collisions of CD planar foils produced fusion neutron yields of the order of 1E6. Analytical formulas for the neutron yield and the results of numerical simulations are compared to the experimental data.

[1] M. Murakami *et al.*, Nucl. Fusion **46**, 99 (2006).
[2] S. P. Obenschain *et al.*, Phys. Plasmas **13**, 056320 (2006).

[1]Work supported by the U.S. Department of Energy and by Japan Society for the Promotion of Science.

BP8.00044 Non-Maxwellian distributions in an IEC device for fusion break even , EVSTATI EVSTATIEV, LANL — We explore the effect of non-Maxwellian distributions on the maximum sustainable ion density in the core of an Inertial Electrostatic Confinement (IEC) device. Ref. 1 considered a negative potential well created by injecting radially monoenergetic electrons. It showed that potential well of 100 KV can be sustained with about 100 A of total injection current. Then Ref. 1 showed that purely monoenergetic, radially moving ions cannot be trapped in a well so created. On the other hand, Maxwellian radial ions can be trapped but there is an upper limit on the core ion density, n_0. If break even balance of fusion yield/ injected (electron) power is considered, this limitation translates into a required electron injection current of the order of 10^{14} A. Clearly, this number is impractical. Natural questions arise from the calculations presented in Ref. 1: Is it possible to find a non-Maxwellian ion distribution (sustainable by some means) such that the necessary electron injection current for creating a trapping potential can be lowered to reasonable numbers? If yes, is such ion distribution energetically viable for fusion break even? Ongoing work indicates positive answer to the first question. We will discuss the energetics of such scheme.

[1] W. C. Elmore, J. L. Tuck, K. M. Watson, Phys. Fluids, vol. 2, 239 (1959).

BP8.00045 Investigation of Stimulated Raman Scattering Using a Short-Pulse Single-Hot-Spot at the Trident Laser Facility[1] , J.L. KLINE, D.S. MONTGOMERY, L. YIN, K.A. FLIPPO, B.J. ALBRIGHT, T. SHIMADA, R.P. JOHNSON, H.A. ROSE, LANL, E.A. WILLIAMS, LLNL, R.A. HARDIN, WVU — A new short-pulse version of the single-hot-spot configuration has been implemented to enhance the performance of experiments to understand Stimulated Raman Scattering. The laser pulse length was reduced from ∼200 to ∼4 ps. The reduced pulse length improves the experiment by minimizing effects such as plasma hydrodynamics and ponderomotive filamentation of the interaction beam. In addition, the shortened laser pulses allow full length 2D particle-in-cell simulations of the experiments. Using the improved single-hot-spot configuration, a series of experiments to investigate kλ_D scaling of SRS has been performed. Quantitative comparisons of the experiments have been made with the VPIC† particle-in-cell code with favorable agreement. In addition, the measurements of the backscatter SRS spectra possibly show evidence of a direct observation of a nonlinear frequency shift due to electron trapping. Details of the experimental setup and initial results will be presented.

[1]Work performed under the auspices of the DOE/NNSA by LANS, LLC., operator of LANL under Contract No. DE-AC52-06NA25396 with the U.S. DOE. †VPIC was developed at LANL by Kevin J. Bowers

BP8.00046 Mitigation of Stimulated Raman Scattering in Hohlraum Plasmas[1] , D.S. MONTGOMERY, J.L. KLINE, H.A. ROSE, S.R. GOLDMAN, LANL, D.H. FROULA, J.S. ROSS, LLNL, R.M. STEVENSON, AWE — One aspect of the research at LANL to control Stimulated Raman Scattering (SRS) in hohlraum plasmas is the investigation of risk mitigation strategies for indirect drive inertial confinement fusion. Beam spray of the laser, due to thermally-enhanced forward Brillouin scattering, results in a decrease in the longitudinal coherence lengths of the laser, which in turn reduces SRS. Since thermal effects depend on Z^2, a small amount of a high Z dopant, 1-2%, can have a large effect. Experiments have been conducted at the Omega laser to test this theory by varying the amount of Xe dopant in C_5H_{12} gas filled hohlraums, and do show a decrease in SRS backscatter as Xe dopant is added. However, there are still uncertainties regarding the responsible mechanism. The second strategy investigated is using high $k\lambda_D$ plasmas to reduce SRS backscatter. Experiments conducted at the Omega laser in hohlraum plasmas determined the critical onset intensity for a range of $k\lambda_D$. A scaling of the critical onset intensity as a function of $k\lambda_D$ has been determined. The scaling is compared with theoretical predictions. Results for both mitigation strategies will be presented, as well as suggested implementation strategies for ignition-relevant hohlraums.

[1]Work performed by LANL under contract DE-AC52-06NA25396

BP8.00047 Multidimensional non local effects in hot spot relaxation in laser-produced plasmas , P.H. NICOLAI, J.L. FEUGEAS, X. RIBEYRE, M. GRECH, G. SCHURTZ, CELIA, University Bordeaux 1, Talence, France — The control of parametric instabilities, such as filamentation and stimulated scattering is a necessity for the Inertial Confinement Fusion (ICF). The plasma temperature and density distribution directly affect the laser beam propagation and the energy deposition. Under sharp gradients created by non-uniform laser heating, the size of hot spots is often comparable to the electron mean free path and the electron heat transport becomes nonlocal. Furthermore, the hot spot form is not necessarily spherical and a one dimensional analysis is insufficient. This work presents the multi-dimensional effects of the non local electron transport on the plasma response induced by a single hot spot or multi hot spots. In addition, in non spherical speckles, we show that crossed gradients of density and temperature generate vortical flows and magnetic fields. These self generated magnetic fields combined with nonlocal heat transport effects [Ph. Nicolai et al Phys. PLasmas **13**, 032701 (2006)] could strongly change the life time of hot spots. Thanks to the use of a 2D multi-physics hydrodynamic code, we investigate the LIL facility quadruplet conditions for long time periods and large plasma conditions [the LIL facility is a full scale bundle of 4 Laser Mega Joule (LMJ) beams]. It appears that in a realistic case, our model indicates a dramatic change of the temperature and density distributions.

BP8.00048 Parametric instabilities and their control in multidimensional nonuniform gain media[1] , MATHIEU CHARBONNEAU-LEFORT, BEDROS AFEYAN, Polymath Research, Inc., MARTIN FEJER, Stanford University — In order to control parametric instabilities in large scale long pulse laser produced plasmas, optical mixing techniques seem most promising [1]. We examine ways of controlling the growth of some modes while creating other unstable ones in nonuniform gain media, including the effects of transverse localization of the pump wave. We show that multidimensional effects are essential to understand laser-gain medium interactions [2] and that one dimensional models such as the celebrated Rosenbluth result [3] can be misleading [4]. These findings are verified in experiments carried out in a chirped quasi-phase-matched gratings in optical parametric amplifiers where thousands of shots can be taken and statistically significant and stable results obtained.

[1] B. Afeyan, et al., IFSA Proceedings, 2003.
[2] M. M. Sushchik and G. I. Freidman, Radiofizika 13, 1354 (1970).
[3] M. N. Rosenbluth, Phys. Rev. Lett. 29, 565 (1972).
[4] M. Charbonneau-Lefort, PhD thesis, Stanford University, 2007.

[1]Work supported by a DOE NNSA SSAA grant. Work of M. F. supported by AFSOR.

BP8.00049 Particle-in-Cell Simulations of the $2\omega_p$ Instability[1] , F.S. TSUNG, W.B. MORI, UCLA, B.B. AFEYAN, Polymath Research Inc — A particle-in-cell code (OSIRIS) is used to investigate the two-plasmon decay instability in nonuniform plasmas of various density profiles. We find good agreement between the simulation and linear theory by Afeyan and Williams (Phys. Plas. **4**, 3827, 1997.) under a variety of laser and plasma conditions relevant to ICF. So far the theory has been tested for linear density profiles and parabolic density profiles where the perfect phase matching (PPMP) point is at the parabolic peak density. We will also test the theory's predictions concerning growth rates and eigeneconditions when the PPMP is in the transition region between the peak density of the parabolic profile and down on the flanks where strictly linear profile behavior is recovered. These simulations allow a check on linear theory, and also demonstrate the ability of PIC codes to study this instability in small regions of ICF relevant targets. Building on these experiences, we have now begun to investigate nonlinear effects on a longer time-scale, such as the saturation mechanism, the spectrum of the fast electrons at saturation, the relaxation and recurrence of the instability, and ion effects.

[1]This work is supported by DOE grant DE-FG52-06NA26195 and NRL.

BP8.00050 Simulation of stimulated Raman scattering in 2D , WOJCIECH ROZMUS, University of Alberta, Edmonton, Alberta, Canadaa, P.-E. MASSON-LABORDE, ZHONGLING PENG, University of Alberta, Edmonton, Alberta, Canada, V.YU. BYCHENKOV, P.N. Lebedev Physics Institute, RAS, Moscow, Russia, C.E. CAPJACK, University of Alberta, Edmonton, Alberta, Canada — Results of particle-in-cell (PIC) simulations of the stimulated Raman scattering (SRS) in one and two spatial dimensions are discussed. With the focus on plasma conditions corresponding to large kλ_D values of SRS driven Langmuir waves (kλ_D > 0.2) we examine secondary instabilities of plasma waves in the presence of trapped particles. For kλ_D > 0.3 transverse trapped particle modulational instability (Rose, Phys. Plasmas **12**, 2005) dominates nonlinear evolution of SRS. We have studied interplay between Langmuir decay and modulation instability in the intermediate regime of kλ_D $\sim$0.2. New effects are examined in two spatial dimensions where large fraction of trapped particles gives rise to electric current of fast electrons and the generation of magnetic field. Magnetic field and the transverse ponderomotive force of localized Langmuir waves modify trapped particle dynamics and alter frequency shift and side loss damping of Langmuir waves. Experimental signatures of the 2D effects such as angular broadening of the backscattered light are discussed.

BP8.00051 pF3d simulations of nonlinear laser propagation in a multi-speckle environment[1] , E.S. DODD, B. BEZZERIDES, D.F. DUBOIS, H.X. VU, LANL — Current design practice focuses on estimating LPI growth with linear analysis and using the average laser intensity [1]. However, LPI growth can be dominated by nonlinear effects, and by the distribution of intensities from the multi-speckle nature of the beam. Recent work on stimulated Raman scattering (SRS) has shown that above a threshold, due to trapped electrons, the reflectivity is greatly increased [2,3]. This threshold also has a dependence on local plasma conditions that differs from the SRS growth rate. In this poster we discuss current work that attempts to understand how the onset of nonlinear Langmuir wave behavior is affected by inter-speckle interactions with the pF3d code [4]. The current work shows that the distribution function for speckle intensities must be taken into account and that the average intensity currently used is insufficient. [1] R. Berger, E. A. Williams, and A. Simon, *Phys. Fluids B* 1 414 (1989). [2] H. X. Vu, D. F. DuBois, and B. Bezzerides, *Phys. Plasmas* 9 1745 (2002). [3] H. X. Vu, D. F. DuBois, and B. Bezzerides, *Phys. Plasmas* 14 012702 (2007). [4] R. L. Berger, C. H. Still, E. A. Williams, and A. B. Langdon, *Phys Plasmas* 5 4337 (1998).

[1]Supported under the DOE/NNSA by the Los Alamos National Security, LLC under contract DE-AC52-06NA25396.

BP8.00052 SRS modeling of NIF ignition designs using pF3D[1] , EDWARD WILLIAMS, DENISE HINKEL, LAURENT DIVOL, A. BRUCE LANGDON, PIERRE MICHEL, C.H. STILL, Lawrence Livermore National Lab — The laser plasma interaction code pF3d is used to model the propagation of high intensity laser beams through plasma, including filamentation and stimulated Raman and Brillouin scattering. Making these calculations feasible for ignition-related applications require that the equations for the light and Langmuir waves be enveloped in both space and time in a "paraxial" approximation. For the SRS light, the time dependence is enveloped around the peak of the (anticipated) spectrum. The Langmuir wave is enveloped around the corresponding parametric matching frequency and wave-number. For homogeneous plasmas, one can arrange for the properties (frequency, damping rate, group velocity, ponderomotive response) of the Langmuir wave, modeled by an enveloped fluid equation, to match those of a kinetic model. This is no longer the case when the plasma conditions span a large range of electron density and temperature. Some compromise is required. In this paper we describe modifications to our pF3d SRS model and compare them with benchmarks. We show simulations of the inner beam of NIF ignition designs, focusing on the behavior of SRS.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California,

BP8.00053 Driven Plasma Waves Relevant to Stimulated Raman Scattering , JAY FAHLEN, BENJAMIN WINJUM, JOHN TONGE, F.S. TSUNG, VIKTOR DECYK, WARREN MORI, University of California, Los Angeles — In fully self-consistent particle-in-cell (PIC) simulations the saturation of Stimulated Raman Scattering (SRS) is quite complicated. To better understand possible saturation mechanisms of SRS, we study the excitation of plasma waves by imposing an external ponderomotive force in 1D electrostatic PIC simulations. By varying the phase velocity and the drive frequency (detuning) with respect to the linear frequency, several saturation mechanisms are explored, including fluid and kinetic nonlinear frequency shifts, sideband generation, and particle trapping. The simulations indicate that simple frequency shift models are inadequate in describing the wave saturation. Wave harmonics are also observed and these can contribute to the non-linear frequency shift. A theory for harmonic-generated frequency shifts in the absence of particle trapping is presented along with corroborating simulation data. Further, the simulations are used to understand the effects necessary for developing a consistent harmonic, kinetic theory. Work supported by DOE under DE-FG52-06NA26195 and NSF under NSF-Phy-0321345. Simulations performed on the DAWSON Cluster.

BP8.00054 The Role of Pump Depletion in Stimulated Raman Scattering for NIF Parameters , B.J. WINJUM, J. FAHLEN, F.S. TSUNG, W.B. MORI, UCLA — Using the full-PIC code OSIRIS in 1D, we have studied stimulated Raman scattering (SRS) in a range of parameters relevant to NIF. In recent years, a wide range of trapped particle effects have been implicated in the behavior of SRS in this regime: detuning due to a kinetic frequency shift, beam modes, electron-acoustic Thompson scattering from these beam modes, and sidebands (the trapped-particle instability). Relatively little mention has been made of pump depletion. We will present results demonstrating that for some parameter ranges, pump depletion due to a convecting scattered packet is the primary mechanism for wave saturation. Furthermore, once pump depletion saturates the instability, the laser can still Raman scatter off the nonlinear, convective plasma wave groups. Once a localized pulse of plasma waves has convected out of the system, or traveled a distance sufficient for convective growth to recur, the instability may restart again. We also show that the behavior changes dramatically when the plasma length becomes much longer than the convective gain length. Work supported by DOE under DE-FG52-06NA26195 and NSF under NSF-Phy-0321345. Simulations performed on the DAWSON Cluster.

BP8.00055 LPI Experiments at the Nike Laser* , J. WEAVER, NRL, J. OH, RSI, B. AFEYAN, Polymath Res., L. PHILLIPS, J. SEELY, C. BROWN, M. KARASIK, V. SERLIN, S. OBENSCHAIN, L.-Y. CHAN, D. KEHNE, D. BROWN, A. SCHMITT, A. VELIKOVICH, NRL, U. FELDMAN, ARTEP, G. HOLLAND, SFA, Y. AGLITSKIY, SAIC — Advanced implosion designs under development at NRL for direct drive inertial confinement fusion incorporate high intensity pulses from a krypton-fluoride (KrF) laser to achieve significant gain with lower total laser energy (E_{tot} ~500 kJ). These designs will be affected by the thresholds and magnitudes of laser plasma instabilities (LPI). The Nike laser can create short, high intensity pulses (t <0.4 ns; I>10^{15} W/cm^2) to explore how LPI will be influenced by the deep UV (248 nm), broad bandwidth (2-3 THz), and induced spatial incoherence beam smoothing of the NRL KrF laser systems. Previous results demonstrated no visible/VUV signatures of two-plasmon decay ($2\omega_p$) for overlapped intensities ~2x10^{15} W/cm^2. We have increased the laser intensity and expanded the range of targets and diagnostics. Single and double pulse experiments are being planned with solid, foam, and cryogenic targets. In addition to spectrometers to study SRS, $2\omega_p$, SBS, and the parametric decay instability, hard x-ray spectrometers (hν >2 keV) and a scintillator/photomultiplier array (hν >10 keV) have been deployed to examine hot electron generation. *Work supported by U. S. DoE.

BP8.00056 Additional Considerations for Laser Plasma Instability Mitigation in Ignition-scale Hohlraums.[1] , WILLIAM KRUER, University of California, Davis — Control of laser plasma instabilities in ignition-scale hohlraums is an important physics challenge, Current hohlraums [1] are designed to minimize the linear instability gains of stimulated Raman and Brillouin backscatter. To complement this work, attention is here given to other possibilities for the excitation of laser plasma instabilities in large hohlraums. Topics addressed include excitation of the two plasmon decay instability, especially by the inner beams in the ablator plasma, as well as cooperative excitation [2] of stimulated scattering by overlapped beams near the laser entrance holes. Particular attention is given to estimating gains and identifying signatures for the cooperative scattering. It is also found that diffraction of the Raman-scattered light wave can reduce the stimulated Raman gain in a speckle but can improve the communication between different ranks of speckles.

[1] D. Callahan, N. Meezan, D. Hinkel, et. al., (private communication)
[2] D. DuBois, B. Bezzerides, and H. Rose, Phys. FluidsB4, 241(1992)

[1]This work was performed under the auspicies of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48 and Agreement B56595.

BP8.00057 Diagnosing Large Simulations of Laser-Plasma Interaction for NIF ignition targets.[1] , BRUCE LANGDON, DENISE HINKEL, STEVE LANGER, BERT STILL, ED WILLIAMS, Lawrence Livermore National Laboratory — We have deployed a variety of diagnostics for the pF3d laser-plasma interaction (LPI) simulation code, which includes paraxial wave optics, multi-species hydrodynamics, and models for stimulated scattering. We present a survey of the diagnostics we use to process the data from the simulations and the directions of their development for very large massively-parallel simulations in support of upcoming 96 beam experiments at NIF next year and ignition. Two examples: Now that we can simulate over the entire beam path in the complex interior of an indirect-drive ignition target, we need to be able to form the spatial distribution of the power absorption of the laser and backscattered light. Such post-processing is itself a parallel processing endeavor due to the large number of spatial cells involved. To compare with experimental near-field streak spectra of backscattered and transmitted light, obtained at the "full aperture backscatter stations", we form synthetic near field streak spectra. For forensic purposes we can also calculate spectra inside the target, which are experimentally inaccessible.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

BP8.00058 SHAPE CONTROL, DIAGNOSTICS, REACTOR DESIGN TECHNOLOGY —

BP8.00059 Microwave Cavities for Pellet Mass Detection on JET[1] , S.K. COMBS, J.B.O. CAUGHMAN, L.R. BAYLOR, D.A. RASMUSSEN, ORNL, A. GERAUD, CEA Cadarache, D. HOMFRAY, UKAEA Fusion Association — Resonant microwave cavities have been built for measuring the mass of pellets that will be created by the new high frequency pellet injector (HFPI) on JET. Two smaller cavities (TE010 mode) have been made for measuring 1 mm size pellets (for ELM mitigation), and two larger cavities (TM010 mode) have been made for measuring 4 mm size pellets (for fueling). Two of the cavities, one each for measuring both size pellets, will be placed near the injector, while the other two will be placed in curved guide tubes located closer to the JET vacuum vessel. Frozen deuterium pellets have been shot through all four cavities at ORNL, with signal levels ranging from 0.7 to 5.0 volts. Pellet mass is determined by measuring the frequency shift caused by the pellet traversing the cavity. The cavities have been calibrated against each other and as a function of their frequency response. Details of the design and testing results will be presented.

[1]Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

BP8.00060 The Ignitor High Speed Pellet Injector* , F. BOMBARDA, S. MIGLIORI, A. FRATTOLILLO, ENEA, Italy, L.R. BAYLOR, J.B.O. CAUGHMAN, S.K. COMBS, D. FEHLING, C. FOUST, J.M. MCJILL, O.R.N.L., G. ROVETA, Criotec Impianti, Italy — A joint ENEA-Frascati and ORNL program for the development of a four barrel, two-stage pellet injector for the Ignitor experiment is in progress. At 4 km/s, pellets can penetrate close to the plasma center when injected from the low field side even for the plasma temperatures expected at ignition. Recent activities carried out at ORNL include improvements to the cryostat, the addition of miniature adjustable heaters in the the freezing zone, and of four close-coupled valves for rapid evacuation of gas after a shot. The LabView application software was successfully used to control the simultaneous formation of D_2 pellets, from 2.1 to 4.6 mm in diameter, that were launched at low speed. ORNL developed, specifically for this application, the light gate and microwave cavity mass detector diagnostics that provide in-flight measurements of the pellet mass and speed, together with its picture. The ENEA two-stage propelling system, now ready for shipping to ORNL, makes use of special pulse shaping valves, while fast valves prevent the propulsion gas from reaching the plasma chamber. Novel experiments, e.g. to create high pressure plasmas in existing devices using this innovative facility, have been envisioned and are being simulated.
*Sponsored in part by ENEA of Italy and by the U.S. D.O.E.

BP8.00061 Design of the IGNITOR Plasma Start-up and Scenarios* , G. RAMOGIDA, G. CENACCHI, A. COLETTI, A. CUCCHIARO, ENEA, Italy, F. VILLONE, F. RUBINACCI, CREATE, Italy, B. COPPI, MIT — IGNITOR is a high field, high plasma current compact experiment designed to be first to reach and study ignited plasma conditions. The design is characterized by a high degree of flexibility obtained by mean of a higher number of poloidal coils and a "large" volume available to the plasma relative to the machine overall dimensions. The most advanced operation scenario (11 MA, 13 T) is based on one that involves the optimal filling of the plasma chamber ("extended First Wall configuration"). The double X-point plasma configuration (X- points on the plasma chamber) enables it to reach ignition with a relatively modest amount auxiliary heating and a sufficient magnetic safety factor in the H-regime. This scenario involves a plasma current of 9 MA with the 13 T maximum toroidal field. Other plasma scenarios with reduced performances are based on a 9 T toroidal field and involve plasma currents of 7 or 6 MA, in the extended First Wall or the double X-point configuration, respectively. The plasma start-up phase has been carefully studied and an optimal choice of the poloidal field coils currents has led to obtaining a relatively large area with a nearly null and flat magnetic field, without reducing the available maximum flux swing (up to 36 Wb) from the Poloidal Field coils system.
*Sponsored in part by ENEA and the US D.O.E.

BP8.00062 Advances in the IGNITOR Plasma Control* , F. VILLONE, R. ALBANESE, G. AMBROSINO, A. PIRONTI, F. RUBINACCI, CREATE, Italy, G. RAMOGIDA, F. BOMBARDA, A. COLETTI, A. CUCCHIARO, ENEA, Italy, B. COPPI, MIT — The IGNITOR vertical position and shape controller has been designed on the basis of the CREATE_L linearized plasma response model, taking into account the engineering constraints of the machine and the features of the burning plasma regimes to be obtained. Special care has been devoted to the design of a robust control system, that can operate even when a degradation of the performance of the electro-magnetic diagnostics may occur. The coupling between the vertical position control and the plasma shape control has been analyzed, in order to allow the plasma vertical position to be stabilized also in the case where a shape disturbance is provoked by a change of the main plasma parameters. Simulations of the control system response have been carried out using realistic models of the electrical power supply system. The non-linear computation of equilibrium flux maps before and after the perturbation shows that the system is able to recover from all the assumed disturbances with this control scheme. In addition, the control of the plasma current and of the separatrix of the double-null plasma configuration is being studied.

*Sponsored in part by ENEA and the US D.O.E.

BP8.00063 Plasma Position Diagnostics for the Ignitor Experiment[1] , G. PIZZICAROLI, F. ALLADIO, F. BOMBARDA, ENEA - Italy, A. LICCIULLI, M. FERSINI, Università di Lecce, Italy, D. DISO, Salentec, Italy, E. PAULICELLI, Università di Bari, Italy — Prototype coils of the electromagnetic diagnostics for the Ignitor experiment have been manufactured adopting innovative methods to improve the ceramic insulator resilience to neutron and gamma radiation. Thus, real time plasma position measurements should be possible over a broader range of high performance plasma regimes with D-D and D-T fuel. An alternative method is under study to provide the necessary spatial information also at the highest parameters that the Ignitor experiment can achieve ($B_T \simeq 13$ T, $I_p \simeq 11$ MA, neutron yield$\simeq 3\times10^{19}$ n/s), where the electromagnetic diagnostics may fail. The new instrument is based on the diffraction and detection of the soft X-ray radiation emitted at the plasma edge. Gas Electron Multiplier (GEM) detectors are considered as the best candidates to provide signals with high counting rates (>1 MHz) and high S/N ratios, to be used by the control system[2]. A curved Multilayer Mirror placed inside one of the equatorial ports will diffract the radiation onto a properly shielded GEM detector that is located outside the machine vacuum and not in direct view of the plasma.

[1]Sponsored in part by ENEA of Italy and by the U.S. D.O.E.

[2]D. Pacella, et al, *Nucl. Instr. Meth. A* **508**, 414 (2003)

BP8.00064 IGNITOR Plasma Chamber Assembly Procedure and Welding Processes* , G. TOSELLI, G. BARBIERI, B. CARMIGNANI, G. CELENTANO, F. COGNINI, A. CUCCHIARO, U. DE MAIO, A. IERINO, T. MINGHETTI, G. PANZANI, S. SANGIORGI, M. TIMPANARO, D. TRESTINI, D. VISPARELLI, ENEA, Italy, B. COPPI, MIT — The appropriate welding techniques to be adopted for the assembly sequences of the 12 sectors of the Plasma Chamber, are described. The last welds, joining two assembled 180^o sectors of the plasma chamber, need to be carried out automatically, at the inside of the Chamber, guided and controlled by the remote handeling system. The deformations and the displacements due to these welds have to be very limited in order to comply with the design geometry of the closed torus and its functions (e.g. support of the First Wall structure). Numerical simulation of the relevant welding processes have been carried out. Two different welding techniques have been chosen.

−Laser welding for the junction of 4 mm of the thickness of adjacent sectors of the plasma chamber

−TIG-NG welding with filler material for the remaining thickness

Experimental tests and corresponding simulations have been made, for both of these welding processes, on suitable samples which reproduce some aspects and geometrical characteristics of the chamber sectors. The most significant results obtained are described and discussed.

*Sponsored in part by ENEA of Italy and by the U.S. D.O.E.

BP8.00065 CATIA-V 3D Modeling for Design Integration of the Ignitor Machine Load Assembly* , A. BIANCHI, B. PARODI, F. GARDELLA, Ansaldo, Ricerche, Italy, B. COPPI, MIT — In the framework of the ANSALDO industrial contribution to the Ignitor engineering design, the detailed design of all components of the machine core (Load Assembly) has been completed. The machine Central Post, Central Solenoid, and Poloidal Field Coil systems, the Plasma Chamber and First Wall system, the surrounding mechanical structures, the Vacuum Cryostat and the polyethylene boron sheets attached to it for neutron shielding, have all been analyzed to confirm that they can withstand both normal and off-normal operating loads, as well as the Plasma Chamber and First Wall baking operations, with proper safety margins, for the maximum plasma parameters scenario at 13 T/11 MA, for the reduced scenarios at 9 T/7 MA (limiter) and at 9 T/6 MA (double nul). Both 3D and 2D drawings of each individual component have been produced using the Dassault Systems CATIA-V software. After they have been all integrated into a single 3D CATIA model of the Load Assembly, the electro-fluidic and fluidic lines which supply electrical currents and helium cooling gas to the coils have been added and mechanically incorporated with the components listed above. A global seismic analysis of the Load Assembly with SSE/OBE response spectra has also been performed to verify that it is able to withstand such external events.

*Work supported in part by ENEA of italy and by the US D.O.E.

BP8.00066 Ignition and Burning Plasma Regimes in the Double Null Configuration of Ignitor* , G. CENACCHI, Italy, A. AIROLDI, IFP-CNR, Italy, B. COPPI, MIT — A new operating scenario for Ignitor with $B_T \approx 13$ T, $I_p \approx 9$ MA and a double X-point configuration (X- points just outside the first wall) has been investigated. The analyses carried out are directed to optimizing the plasma volume, the magnetic configuration and the relevant "safety factor" near the first wall. A transport analysis has been performed to simulate the current density evolution (important for the considered sequences of equilibrium configurations) and to verify the possibility of accessing H-regimes. The H-regime power threshold has been estimated from recent scalings based on a variety of experiments. This threshold power is consistent with that available from the provided ICRH system, combined with the Ohmic and α-particle heating. In the numerical simulations a volume average density $\langle n_e\rangle \approx 3\times10^{20}\mathrm{m}^{-3}$, an average $Z_{eff} \approx 1.5$, and 3 MW of ICRH a power absorbed by the plasma have been considered. Ignition and advanced parameters as those expected for the "standard" 11 MA scenario with the "extended" first wall configuration of Ignitor can be reached. Even without accessing the H-regime and with pessimistic assumptions about the energy confinement time, plasma conditions of relevance to the physics of burning plasmas can be attained.

*Sponsored in part by ENEA and CNR of Italy and by the US D.O.E.

BP8.00067 ICRH Physics in the Ignitor Experiment* , A. CARDINALLI, ENEA, Italy, G. CENACCHI, A. AIROLDI, CNR-IFP, Italy, B. COPPI, MIT — The Ignitor ICRH sytem can operate in a broad frequency range (80-120 MHz) and with significant levels of delivered power (4 to 12 MW). The frequency band is consistent with the use of magnetic fields in the range 9-13 T. In this work a review of the ICRH physics is presented for i) full performance scenarios, ii) reduced parameters scenarios, and iii) double X- point configurations at 13 T and 9 MA. In all cases the ICRH is used to control the plasma temperature, to accelerate the achievement of ignition in the extended first wall configuration ($I_p \cong 11$ MA), and to help the transition to the H-regime in the X-point configuration. The power deposition profiles on ions and electrons are obtained by using a full wave code in a toroidal geometry configuration and are used as input data for a transport analysis. In particular, calculations show that a small fraction of ^{3}He (1-2%) improves the wave absorption on ions near the center of the plasma column, while a substantial fraction of the coupled power, owing to the $n_{\|}$-spectrum radiated by the antenna, is damped on the electrons in a broad radial interval of the plasma column. The conclusion is that in Ignitor, given the flexibility of its ICRH system, it is possible to control the plasma temperature and the transition to the H-mode in the X- point scenarios with relatively modest amounts of ICRH power (< 8 MW).

*Sponsored in part by ENEA and by the U.S. D.O.E.

BP8.00068 The IGNITOR ICRH Antenna Design with TOPICA

, RICCARDO MAGGIORA, VOLODYMYR KYRYTSYA, DANIELE MILANESIO, ORSO MENEGHINI, GIUSEPPE VECCHI, Politecnico di Torino — A flexible auxiliary Ion Cyclotron Resonance Heating (ICRH) system (f = 80 – 120 MHz) has been included in the IGNITOR machine design. ICRH systems have been successfully tested on a number of existing devices especially at high density. Ignition can be accelerated significantly by relatively low levels of ICRH (about 5 MW, a fraction of the final fusion heating) when applied during the current ramp-up. In addition, ICRH provides a useful tool to control the evolution of the current density profile. Four antennas, each composed by 4 straps independently fed by 4 matching systems, can deliver a minimum RF power of about 12 MW in the entire adopted frequency range. The possibility of adding two more antennas has been considered. The antenna design and optimization have been based on the simulation results obtained with TOPICA (Torino Polytechnic Ion Cyclotron Antenna code)[1].

[1] V. Lancellotti et al., Nuclear Fusion, **46** (2006) S476-S499

BP8.00069 High temperature transient heating experiments on C in a Be seeded plasma in PISCES B.[1]

, J. HANNA, D. NISHIJIMA, R.P. DOERNER, M. BALDWIN, K.R. UMSTADTER, R. SERADARIAN, R. HERNANDEZ, UCSD, R. PUGNO, IPP — An experimental investigation of the effects of transient heating on Be films on C substrates in deuterium plasmas has been conducted in PISCES-B. It has been shown previously that Be film growth on C can form carbide layers that reduce the chemical erosion of C during deuterium ion bombardment. Results from transient heating up to 1200°C have also been reported. In this presentation, results on the chemical erosion and on deuterium retention in C targets with heat pulses up to 2000°C will be presented. A scaling expression for chemical erosion suppression due to Be2C formation developed previously will be extended to include transients with varying peak surface temperature and duty cycle using an integrated time-temperature, with a temperature range of 300 to 2000°C.

[1]This work was supported by grant DE-FG03-95ER-54301 from the US DoE.

BP8.00070 The Effect of MHD Noise on the Vertical Observer in Tokamaks

, GIANPAOLO TURRI, STEFANO CODA, YVES MARTIN, JEAN-MARC MORET, OLIVIER SAUTER, École Polytechnique Fédérale de Lausanne (EPFL), Centre de Recherches en Physique des Plasmas, Association Euratom, CH-1015 Lausanne Suisse — The spurious perturbations induced by MHD instabilities on the Tokamak à Configuration Variable (TCV) vertical position observer are investigated. The study is performed for ITER-relevant ELMs (involving high heat fluxes, and with geometry compatible with the ITER constraints), sawteeth, and magnetic islands on the q=2-3 rational surfaces. In addition, "infernal" mode instabilities appearing in reverse shear are analyzed. A modified observer is calculated such as to minimize the MHD noise propagation for each case, based on three constraints: 1) equivalent response to a real vertical displacement event (VDE), based on VDE analysis; 2) minimized distance in the least squares sense from the optimized default observer; 3) orthogonality with the magnetic response to an MHD event. The result of the minimization is applied to the single instability for which it is designed, to verify the validity of the approach. In addition to that, mixed-mode observers are used to evaluate the effect of noise propagation in discharges with multiple modes. The results confirm that the design of a discharge-specific vertical observer should be sufficient for safely controlling the vertical position of the plasma in ITER.

BP8.00071 X-ray diagnostic for monitoring the charge state distribution in an ECR ion source[1]

, BRIAN CLUGGISH, IOAN-NICULAE BOGATU, LIANGJI ZHAO, JIN SOO KIM, FAR-TECH, Inc. — FAR-TECH, Inc. is developing a non-invasive X-ray spectral diagnostic to monitor the charge state distribution (CSD) in an electron cyclotron resonance ion source (ECRIS). The ECRIS is magnetic mirror confined plasma device in which electrons undergo ECR heating. Consequently the electron distribution function (EDF) develops a non-Maxwellian "tail" with energies over 10 keV. This in turn results in an ion CSD dominated by multiply charged ions. FAR-TECH, Inc. will determine the EDF by measuring the bremsstrahlung X-ray spectrum between 3 and 100 keV. The CSD can then be determined using our Generalized ECRIS Model (GEM) which calculates the rate of ionization to each charge state using the EDF. Measurements of the X-ray spectrum and the resulting EDF's will be presented. The simulations will be compared to Faraday cup measurements of the CSD of ions extracted from an ECRIS.

[1]This research supported by a U.S. Dept. of Energy SBIR grant

BP8.00072 Ion Velocity Distribution Functions in a Compact, Expanding, Helicon Plasma

, DANIEL LEWIS, ALEXANDER HANSEN, EARL SCIME, West Virginia University Department of Physics — Previous laser induced fluorescence (LIF) measurements of ion velocity distribution functions in a compact, expanding helicon plasma were limited by the available laser power and optical access [*Keesee et al.*, Phys. Plasmas **12**, 093502 (2005)]. Here we present LIF measurements of the ivdf in argon plasmas in the CHEWIE compact helicon source as a function of fill pressure, source magnetic field, and partial pressure of argon. The LIF measurements were accomplished with a ring dye laser tuned to 611.662 nm (vacuum wavelength) to pump the Ar II $3d^2\mathrm{G}_{9/2}$ metastable state to the $4p^2\mathrm{F}_{7/2}$ state and observing the fluorescent emission at 460.96 nm photons. RF power up to 600 W is used to create a steady state plasma in the 12 cm long, 6 cm diameter Pyrex source chamber. One end of the source chamber is connected to a 30 cm long, 15 cm diameter expansion chamber. The magnetic field strength ranges from 0 to 850 Gauss. We will present measurements of argon ivdfs for gas flow rates of 10, 20, 30 sccm at constant rf power and magnetic field.

BP8.00073 Absorption Spectroscopy Measurements of Ion Velocity Distribution Functions in Argon Plasmas.

, EARL SCIME, WILLIAM S. PRZYBYSZ, West Virginia University — The scarcity of strong absorption lines in accessible tuning ranges along with plasma saturation due to low ion population densities makes absorption spectroscopy of helium ions notoriously difficult. Helicon plasmas, with their characteristically high ion densities, are a good candidate for initial helium ion spectroscopy experiments. However, preliminary measurements of Doppler broadened ion velocity distribution functions (ivdf) involving injecting a tunable infrared diode laser, tuned to 1012.36 nm and chopped roughly at 1kHz, along the axis of a 1.5m long helicon plasma have yielded erratic and irreproducible measurements. Here we present absorption spectroscopy measurements of ivdfs in argon helicon plasma using a tunable diode laser at 668.43 nm to pump the Ar II metastable $3\mathrm{d}^4\mathrm{F}_{7/2}$level to the $4\mathrm{p}^4\mathrm{D}_{5/2}$ level. The optimized multi-pass optical configuration and the ratioing detector will be described and initial measurements presented. Once the absorption measurement technique is optimized for the well-known and more easily diagnosed Ar II transition, the same experimental configuration will then be used for the infrared helium ion absorption measurement

BP8.00074 Optical diagnostic suite for measuring plasma velocity, laser-ablated metal topography and electron density

, ANTHONY VALENZUELA, GEORGE RODRIGUEZ, MPA-CINT, Los Alamos National Laboratory, STEVEN CLARKE, W-6, Los Alamos National Laboratory — We report on the capabilities of our diagnostic system to measure plasma properties including longitudinal velocity, topography of an ablation region and transverse electron density. We generate a plasma by ablating a thin metal film on a transparent substrate with a nanosecond millijoule laser pulse. We use a heterodyne-based Photonic Doppler Velocimeter (PDV) system to measure the velocity of the plasma plume. We also use a Shack-Hartmann interferometer (DOTS) to record the topography of the ablated metal. Also, we extended the functionality of DOTS to examine the transverse electron density of plasma channel in air generated by an intense, self-focused laser pulse. We compare the experimental data in the first two cases to hydrodynamic simulations to provide a feedback loop to improve our theoretical models.

BP8.00075 Method to Estimate the Electron Temperature and the Neutral Density in a Plasma from Spectroscopic Measurements Using Argon Atoms and Argon Ions Collisional-Radiative Models[1]

, ELLA M. SCIAMMA, ROGER D. BENGTSON, KEVIN E. CASEY, W.L. ROWAN, The University of Texas at Austin, AMY M. KEESEE, West Virginia University, CHARLES A. LEE, DAN BERISFORD, KEVIN LEE, KENNETH GENTLE, The University of Texas at Austin — We present a method to infer the electron temperature in argon plasmas using a collisional-radiative model for argon ions [1] and measured electron density to interpret absolutely calibrated spectroscopic measurements of argon ion (Ar II) line intensities. The neutral density, and hence the degree of ionization of this plasma, can then be estimated using spectroscopic argon atoms (Ar I) line intensities and a collisional radiative model for argon atoms [2]. This method has been tested for plasmas generated on two different devices at the University of Texas at Austin: the helimak experiment and the helicon experiment. We present results that show good correlation with Langmuir probe measurements.

[1] http://adas.phys.strath.ac.uk
[2] Amy. M. Keesee and Earl E. Scime. Rev. Sci. Instrum. 77, 10F304 (2006).

[1]Work supported by Ad Astra Rocket Company and the Department Of Energy Office of Fusion Energy Science DE-FG03-00ER54609.

BP8.00076 A Novel X Ray Source for Cancer Radiotherapy

, ILIJA DRAGANIC, National Institute of Standards and Technology, Gaithersburg, MD 20899-8422, USA, JACEK CAPALA, National Cancer Institute, National Institute of Health, Bethesda, MD 20892, USA, JOHN GILLASPY, National Institute of Standards and Technology, Gaithersburg, MD 20899-8422, USA — There is a growing interest in exploring the possibility of replacing conventional broadband x-rays used in biomedicine with narrowband x-rays. In a form of binary therapy, drugs containing heavy elements are made to preferentially concentrate in cancer cells, and then the x-ray wavelengths are tuned to match the photo absorption peaks of the heavy elements. Synchrotrons can provide the necessary x-ray beams, but are impractical for routine therapy. An EBIS/T device may be a suitable alternative. EBIS/T devices can produce slow highly charged ions (HCI) which can be easily transported into the body through a cannula, where they produce relatively monoenergetic x rays within the tumor. In order to achieve the highest charge states with sufficient fluence for use in biomedicine, a better understanding of the EBIS/T ion trap dynamics may be required. This work will address the optimal ion temperatures, spatial distributions, densities, and related parameters of HCI in the trap using optical spectroscopy.

BP8.00077 ASTROPHYSICAL PLASMAS: EXPERIMENT AND THEORY —

BP8.00078 The Magnetothermal Instability And Its Role In Angular Momentum Transport in Hot, Dilute Magnetized Accretion[1]

, TANIM ISLAM, University of Virginia & École Normale Supérieure — Recent observations have demonstrated the prevalence of underluminous accretion flows in massive and supermassive central galactic black holes, for which the best studied example is that of Sagittarius A* at the center of our Milky Way. In addition, circular polarization measurements of millimeter-wavelength radiation from Sagittarius A* has shown the existence of measurable magnetic fields in the source. These flows are characterized by the radiatively inefficient accretion of a hot, mildly collisional to highly collisionless, and optically thin plasma onto a black hole. The energy generated through the accretion of matter down a gravitational well cannot be efficiently radiated and therefore must be advected outwards. We show that the collisionless and mildly collisional MTI, an MHD mode of a dilute rotationally supported plasma, can destabilize these dilute, magnetized, radiatively inefficient flows and can carry out angular momentum and energy in order to allow accretion to occur.

[1]the author wishes to acknowledge the support of the Laboratorie de Radioastronomie of the Ecole Normale Superieure, and the University of Virginia Department of Astronomy

BP8.00079 Finite Larmor Radius Effects on the Magnetorotational Instability

, N.M. FERRARO, Princeton Plasma Physics Laboratory — The linear dispersion relation for the magnetorotational instability (MRI) has been derived including gyroviscosity, which represents finite Larmor radius (FLR) effects in the Braginskii equations [1]. It is shown that FLR effects are the most important effects in the limit of weak magnetic fields for ionized disks, and are much more important than the Hall effect when $\beta_i \gg 1$, where β_i is the ratio of the ion thermal pressure to the magnetic pressure. FLR effects may completely stabilize even MRI modes having wavelengths much greater than the ion Larmor radius. Some implications for astrophysical accretion disks are discussed. The results of fluid simulations of accretion disks using M3D-C^1, a toroidal axisymmetric extended-MHD code which includes two-fluid and gyroviscous effects, are presented.

[1] N. M. Ferraro, *ApJ* **662**(1):512 (2007)

BP8.00080 Poloidal rotation and its effect on toroidal rotation

, O.D. GURCAN, P.H. DIAMOND, University of California, San Diego, T.S. HAHM, Princeton Plasma Physics Laboratory — A transport model, which describes the self-consistent evolution of poloidal and toroidal rotation in addition to density and pressure is suggested. The model is self consistent in the sense that Er shear is used for symmetry breaking, but its effect on turbulence is also considered. We also solve the poloidal ion momentum equation together with the radial force balance relation. The full study involves a rigorous gyrokinetic derivation of the model, and numerical solutions of the simple 1-D transport model. Notice that the simplicity of the model allows parameter scans that require many runs. The results of this study will be presented.

BP8.00081 Initial results from the Princeton Magnetorotational Instability Experiment using liquid metal

, M.D. NORNBERG, E. SCHARTMAN, H. JI, CMSO and PPPL, M.J. BURIN, California State-San Marcos, W. LIU, CMSO and PPPL, J. GOODMAN, Princeton University — The Magnetorotational Instability (MRI) is regarded as the dominant mechanism for accretion disk turbulence and its associated angular momentum transport. A series of experiments using both water and liquid metal in a novel wide-gap Taylor-Couette apparatus are conducted to elucidate the relative importance of sub-critical hydrodynamic turbulence to the MRI. Reynolds stress measurements using two-component laser Doppler velocimetry in water demonstrate that keplerian-like flows have extremely weak angular momentum transport even at Reynolds numbers up to 10^6 when end effects are suppressed by differentially rotating end caps. By switching the working fluid to a liquid Gallium alloy (Ga-In-Sn), this quiescent flow can be destabilized by applying an axial magnetic field of up to 5 kG. The growth rate of the MRI is determined from external magnetic field measurements using radially-aligned induction coils and Hall probes. Secondary circulation induced by the MRI, which is a local instability, is distinguished experimentally from magnetically-induced Ekman circulation generated by the boundary layers through comparisons between flows which are stable and unstable to the MRI. This work is supported by DOE, NASA, and NSF.

BP8.00082 The Princeton MagnetoRotational Instability (MRI) Experiment - Apparatus and Diagnostics

, ETHAN SCHARTMAN, MARK NORNBERG, HANTAO JI, PPPL, CMSO, MICHAEL J. BURIN, California State University, San Marcos, JEREMY GOODMAN, Princeton University — The Princeton MRI experiment investigates instabilities believed to be responsible for angular momentum transport in accretion disks. The apparatus consists of fluid confined between a pair of concentric spinning cylinders. The shear flow developed shares with accretion disks the properties of linear hydrodynamic stability and outwardly-decreasing angular velocity. Onset of instability in this apparatus is relevant to studies of turbulent transport in astrophysical disks. Using water or a liquid Gallium alloy we investigate Subcritical Hydrodynamic Instability (SHI) or the MRI. The cylinder end caps are divided into two pairs of differentially-rotatable rings to reduce the impact of the vertical boundaries on the bulk flow. When using water the Reynolds stress is directly measured using 2-component Laser Doppler Velocimetry. During Gallium operation a 5kG axial magnetic field is applied. Radial motions of the fluid generate a fluctuating radial component of the magnetic field which is detected by an array of magnetic B-dot coils external to the flow. For the largest flow shear in our apparatus the radial fields will be generated by the MRI. To test the operation of the B-dot coils the magnetic field is applied to a Rayleigh-unstable flow. Supported by DOE, NASA and NSF.

BP8.00083 Axisymmetric Simulation of the Magnetorotational Instability in a Magnetized Taylor-Couette Flow[1]

, WEI LIU, PPPL, JEREMY GOODMAN, Princeton University, HANTAO JI, PPPL — The magnetorotational instability (MRI) is probably the main cause of turbulence and accretion in sufficiently ionized astrophysical disks. Despite much theoretical and computational work, however, the nonlinear saturation of the MRI is imperfectly understood. We present non-ideal magnetohydrodynamic simulations of the Princeton MRI experiment. In vertically infinite or periodic cylinders, MRI saturates in a resistive current-sheet with significant reduction of the mean shear, and with poloidal circulation scaling as the square root of resistivity. Angular momentum transport scales as the reciprocal square root of viscosity but only weakly depends on resistivity. For finite cylinders with insulating end caps, a method to implement full insulating boundary condition is introduced. MRI grows with a clear linear phase from small amplitudes at rates in good agreement with linear analysis. In the final state one inflowing "jet" opposite to the usual Ekman "jet" is found near the inner cylinder. Angular momentum transport has a weaker scaling with Reynolds number and is dependent hardly on Lundquist number. Under proper condition our experimental facility is a good testbed to show that MRI could be suppressed by a strong magnetic field.

[1]supported by DoE, NASA and NSF.

BP8.00084 Numerical Studies of Boundary Layers in the Princeton MRI Experiment[1]

, AUSTIN ROACH, HANTAO JI, WEI LIU, JEREMY GOODMAN, Center for Magnetic Self-Organization, PPPL — The Princeton MRI experiment uses a Taylor-Couette apparatus to generate rotating shear flows for the investigation of the magnetorotational instability. Discrepancies have been observed between the experimentally measured fluid flow profiles and those expected from hydrodynamic simulation of the experimental apparatus with the 2-dimensional code ZEUS-2D. While experimental adjustments have been made to produce the desired flow profiles in the apparatus for the investigation of the MRI, an explanation for the difference between the experimental measurements and computational prediction of the fluid flows has not yet been found. An attempt is now being made to account for these differences by adding to the simulations additional effects, such as noisy boundary layers and a more detailed description of the geometry of the experiment. Results of these computational investigations and a comparison to experimental results will be presented.

[1]This work supported by DOE contract number DE-AC02-76-CHO3073.

BP8.00085 An Experimental Study of Turbulent Boundary Layers in Free-Surface MHD Flows

, J. LUC PETERSON, MARK NORNBERG, HANTAO JI, ALEX GILL, Princeton University, DIMITRIS GIANNAKIS, University of Chicago — Descriptions of the turbulent boundary layers in astrophysical and laboratory plasmas require an understanding of free-surface magnetohydrodynamic (MHD) stability. The dynamics of the plasma ocean on the surface of nuetron stars in binary systems could relate to X-Ray burst phenomena, while turbulent flows in liquid metal diverters are useful for effective heat transport from the core of a fusion reactor. The Liquid Metal eXperiment (LMX) at PPPL is a small-scale laboratory experiment using liquid gallium alloy designed to study free-surface MHD stability and wave propagation. LMX is a short wide-aspect ratio channel (1 by 15 by 70 cm) designed for Reynolds numbers of 10000 under an imposed magnetic field of 7 kG. Extensive hydrodynamic experiments have demonstrated the ability to create stable turbulent boundary layers in short open channels. The transition to liquid metal operations will be discussed, with particular attention paid to new flow velocity diagnoistic tools and techniques for creating stable turbulent boundary layers. This work supported by DoE under contract #DE-AC02-76-CH03073.

BP8.00086 Laboratory Study of Magnetorotational Instability (MRI) in a Helicon Plasma

, H. JI, Princeton Plasma Physics Laboratory, J. FOLEY, F. LEVINTON, Nova Photonics, B. FETROE, Y. RAITSES, J. KEFELI, M. NORNBERG, S. ZWEBEN, M. YAMADA, Princeton Plasma Physics Laboratory — Fast angular momentum transport in accretion disks has been an outstanding problem in astrophysics for more than three decades. Classically estimated transport due to molecular viscosity of a neutral fluid is too small to account for the fast observed accretion rates. The magnetorotational instability (MRI) has been identified as a powerful mechanism to transport angular momentum. Experiments using liquid metal are underway to study the MRI in the incompressible MHD limit. A new frontier in accretion disk research is to explore physics beyond the incompressible MHD. Possible new effects include compressibility, multiple-fluid effects, kinetic effects, ion-neutral collisions, radiation pressure, and dust grains. In order to study some of these effects, a new, small-scale experiment using a helicon plasma has been constructed. A preliminary analysis, addressing the two-fluid or Hall effect based on a local Hall MHD formulation, shows large differences in the growth rate between the cases when magnetic field is parallel and anti-parallel to the rotation axis for the experimentally achieved parameters. This is a clear sign of Hall effects on MRI. The detailed analyses and experimental results will be presented when available.

BP8.00087 Magnetorotational instability in electrically driven flow: theoretical predictions and experimental observations[1]

, IVAN KHALZOV, ANDREI SMOLYAKOV, University of Saskatchewan, VICTOR ILGISONIS, RRC Kurchatov Institute — The electrically driven flow of liquid metal in circular channel is efficient way to test magnetorotational instability (MRI) in laboratory. The main body of this flow has the equilibrium rotation law $\Omega(r) \propto 1/r^2$, which is stable hydrodynamically but can be unstable with respect to MRI. We study numerically the linear stability of such flow in the circular channel of finite hight in the presence of vertical magnetic field in the frame of dissipative incompressible magnetohydrodynamics (MHD). Marginal stability curves in the plane Hartmann number – Reynolds number are calculated for the range of azimuthal wave-numbers $m = 0 \div 200$. It is shown that for larger Hartmann numbers the threshold of instability is determined by modes with higher m. Our numerical results are found to be in a good agreement with available experimental data.

[1]This work is supported in part by NSERC Canada

BP8.00088 Physics of Plasma Accreting Structures* , F. ROUSSEAU, E.N.S., Paris, B. COPPI, MIT — Plasma accretion is considered to take place within thin differentially rotating structures, (sequence of density rings[1]) in the prevalent gravity of a central object where the vertical confinement is provided by the Lorentz force associated with internal toroidal currents. The factors that are needed to complete the solution of the equations[1] that describe "ring configurations" are identified and included in the relevant analysis. The relationship between poloidal flows and "seed" magnetic fields is uncovered and analyzed[2]. The significance of the symmetries of the poloidal currents that are found to be associated with the presence of an effective viscosity is pointed out. The problem of having a radial inflow velocity in a two-dimensional configuration with internal currents has been dealt with in the limit of very small "seed" magnetic fields by finding a narrow family "open" magnetic surfaces on which the plasma can spiral toward the central object[2]. *Sponsored in part by the US D.O.E.

[1]B. Coppi and F. Rousseau, *Ap. J.*, **641**, 458 (2006)

[2]B. Coppi and F. Rousseau, Paper O4.034, Proceedings of the 2007 E.P.S. Conference on Plasma Physics and MIT-LNS Report 07/06

BP8.00089 Non-axisymmetric Ballooning Modes in Thin Accretion Structures , CHRIS CRABTREE, BRUNO COPPI, MIT — The consideration of non-axisymmetric modes in thin accretion structures has been shown to be relevant to the issue of angular momentum transport [1]. To this end we consider the stability of differentially rotating, $u_\phi = R\Omega(R)$, axisymmetric equilibria with cylindrical magnetic flux surfaces to perturbations with large toroidal mode numbers $n_0 \gg 1$. Assuming the equilibrium plasma rotation is approximately Keplerian about a central compact object and the rotation speed is smaller than the thermal speed, the equilibrium pressure and density depend on both R and z. We seek linear solutions to the ideal MHD equations by expanding in the small parameter $1/n_0$ and satisfying requirements similar to those used for ballooning modes in magnetically confined toroidal plasmas: 1) the wavelength parallel to the magnetic field is relatively small, 2) the mode approximately corotates with the plasma, and 3) the compressibility is small but non-zero. Normal mode solutions are constructed using a radially dependent toroidal mode number which is inversely proportional to the rotation frequency such that $k_\phi \sim n_0\Omega_0/u_\phi(R)$ where Ω_0 is a constant. Toroidally periodic perturbations are then constructed with a formalism that is typically used in the theory of ballooning modes in toroidal configurations to enforce periodicity in the poloidal direction in the presence of magnetic shear. [1] B. Coppi, P. Coppi *Ann. Phys.* **291**, 134 (2001) *Supported by U.S. D.O.E.

BP8.00090 Modeling the spectral evolution of prompt GRBs and X-ray flares[1] , S. POTHAPRAGADA, S. REYNOLDS, S. GRAHAM, M.V. MEDVEDEV, University of Kansas — We use the detailed theory of jitter radiation from relativistic shocks containing small-scale magnetic fields and relativistic shock kinematics to build a numerical model of spectral variability of GRB emission. It is, then, applied to the conditions of the internal shocks in order to model the prompt phase and X-ray flares. We derive the lighcurves, spectral evolution in time within each sub-pulse of a prompt GRB and during an X-ray flare. Correlations of spectral parameters are also deduced. We demonstrate that the model lightcurves and spectra agree well with observation data. We discuss how one can deduce certain parameters of the plasma of the shock and the ejected material.

[1]Supported by DoE grants DE-FG02-04ER54790 and DE-FG02-07ER54940 and by NASA grant NNX07AJ50G.

BP8.00091 Phase-space distribution of accelerated electrons in Weibel-mediated relativistic GRB shocks[1] , S. GRAHAM, S. POTHAPRAGADA, S. REYNOLDS, M.V. MEDVEDEV, University of Kansas — The shock model of gamma-ray bursts (GRBs) contains two equipartition parameters: the magnetic energy density and the kinetic energy density of the electrons relative to the total energy density of the shock, ϵ_B and ϵ_e, respectively. These are free parameters within the model. Whereas the Weibel shock theory and PIC simulations fix ϵ_B at the level of ~few$\times(10^{-3}...10^{-4})$, no understanding of ϵ_e existed until recently. Medvedev (2006) has demonstrated that it inevitably follows from the Weibel shock theory that $\epsilon_e \simeq \sqrt{\epsilon_B}$. Extrapolating the theory to GRB afterglow shocks, we find that observational data agree with our theoretical prediction. It has been suggested that the $\epsilon_e - \epsilon_B$ relation can be used to reduce the number of free parameters in afterglow models. Here we further develop the model of non-Fermi acceleration of electrons in prompt GRBs. We developed a numerical code, which computes full phase space distribution of electrons in Weibel electromagnetic fields. This distribution is further used to compute the electron energy distribution, the distribution over pitch-angle, the angular pattern of jitter emissivity, etc.

[1]Supported by DoE grants DE-FG02-04ER54790 and DE-FG02-07ER54940 and by NASA grant NNX07AJ50G.

BP8.00092 Jitter radiation produced by electrons with anisotropic distribution in Weibel turbulence of GRBs and lab experiments[1] , S. REYNOLDS, S. GRAHAM, S. POTHAPRAGADA, M.V. MEDVEDEV, University of Kansas — Radiation emitted by relativistic electrons propagating through the random, skin-depth-scale magnetic fields produced by the Weibel instability is referred to as the Jitter radiation. These fields are associated with current filaments and, hence, their spatial distribution is anisotropic. This anisotropy of fields has been shown to result in anisotropic radiation spectrum (even if the electron distribution is isotropic) that depends on the angle between the line of sight and the direction of current filaments. The study of the electron distribution in the Weibel turbulence shows that the electron PDF is also anisotropic, with the direction of anisotropy being along the filament orientation. Therefore, accurate calculation of the emitted spectra shall account for the PDF angular structure as well. Here we formulate the jitter radiation theory in a general set-up, thus generalizing previous results to an arbitrary PDF. We calculate model spectra and discuss implications of the results to emission from ultra-relativistic shocks of gamma-ray bursts and to Laboratory Astrophysics experiments with petawatt-scale lasers.

[1]Supported by DoE grants DE-FG02-04ER54790 and DE-FG02-07ER54940 and by NASA grant NNX07AJ50G.

BP8.00093 Transport Properties of Laser Plasma and H-Rich White Dwarf Stars , VITHAL L. PATEL[1], Berkeley Research Associates, Inc., JAECHUL OH, Research Support Instruments, Inc. — An extended survey of spectroscopic observations of hydrogen-rich white dwarf stars indicates existence of magnetic fields of 10kG-10MG [1]. High intensity laser interactions with matter generates magnetic fields of several 100s MG [2]. In both laboratory laser plasma as well as astrophysical plasmas, weakly Landau quantization may be present. We consider transport properties of such plasmas following work of Potekhin [3]. With some simplification, estimate of transport coefficients can be made without evaluation of elaborate integration. This research was performed in Laser Plasma Branch, Plasma Physics Division, Naval Research Laboratory and was supported by DOE/NNSA.
[1] A. Kawka et. al., ApJ, 654, 499, 2007
[2] S. Eliezer et. al., Phys. Plasmas, 12, 052115, 2005
[3] A. Y. Potekhin, Astron. Astrophys., 346, 345, 1999

[1]Permanent Address: Arizona Senior Academy,13867 E. Langtry Ln, Tucson, AZ.

BP8.00094 Numerical study of ultra-relativistic electromagnetic filamentation in boosted frames , S.F. MARTINS, IST - Lisbon, R.A. FONSECA, ISCTE - Lisbon, IST - Lisbon, W.B. MORI, UCLA, L.O. SILVA, IST - Lisbon — We address the simulation of relativistic shocks in astrophysics, namely the numerical implications of ultra-relativistic particles and the large time/space scales associated with these systems. It was recently shown [1] that performing simulations in optimized Lorentz frames can decrease simulation run times by orders of magnitude, completely changing computational resources required. The Lorentz transformation for a boosted frame was implemented in osiris 2.0 [2] and encompassed several difficulties that will be discussed. For instance, transformation of quantities back to the laboratory frame may require massive data handling and complex diagnostic/visualization, and can cancel the potential gains from the time scale reduction due to the boost. The possibility of using a boosted frame to suppress numerical noise (e.g. due to numerical Cerenkov radiation) will also be explored.

[1] J.-L. Vay, PRL 98, 130405 (2007)
[2] R. A. Fonseca et al, Lecture Notes in Computer Science 2329, III-342 (Springer-Verlag, 2002)

BP8.00095 Colliding Laser-Produced Plasmas on LaPD[1] , ANDREW COLLETTE, WALTER GEKELMAN, UCLA — The expansion and interaction of dense plasmas in the presence of a magnetized background plasma is important in many astrophysical processes, among them coronal mass ejections and the many examples of plasma jets from astrophotography. Turbulence is expected to be present in many such configurations. We describe a series of experiments which involve the collision of two dense (initially, $n > 10^{15}\text{cm}^{-3}$) laser-produced plasmas within an ambient, highly magnetized plasma. The laser-produced plasmas form diamagnetic cavities in which a large percentage of the background magnetic field (600G) has been expelled. First-stage observations using a fast (3ns exposure) camera indicate complicated structure at late times, in addition to coherent corrugated structures on the bubble surfaces. The data hint at the presence of turbulence in the interaction. The second stage of observation consists of direct investigation of the magnetic field using probes. A novel diagnostic system composed of small (300-500 micron) 3-axis differential magnetic field probes in conjunction with a ceramic motor system capable of extremely fine (sub-micron) positioning accuracy is currently under development. An ensemble of magnetic field data from fixed and movable probes makes possible the calculation of the cross-spectral function.

[1] Research performed under F.E.S. Fellowship Program (ORISE/DOE).

BP8.00096 Three-dimensional RAGE Simulations of Strong Shocks Interacting with Sapphire Balls , B.H. WILDE, R.F. COKER, LANL, P.A. ROSEN, J.M. FOSTER, AWE, P. HARTIGAN, R. CARVER, Rice, B.E. BLUE, GA, J.F. HANSEN, LLNL — The goal of our 2007-2008 NLUF experiments at the OMEGA laser facility is to investigate the physics associated with the interaction of strong shocks and jets with clumpy media. These experiments have close analogs with structures observed in a variety of astrophysical flows, including jets from young stars, outflows from planetary nebulae, and extragalactic jets. In these experiments, a multi-mega bar shock is created in a plastic layer by heating a hohlraum to 190 eV temperature with 5 kJ of laser energy. The shock enters a 0.3 g/cc RF foam into which are embedded 500 micron diameter sapphire balls. The shock shears off the ball such that it creates thin two-dimensional sheets of sapphire which subsequently break up and undergo the three-dimensional Widnall instability (Widnall, S. E., Bliss, D. B., & Tsai, C. 1974, J. Fluid Mech., 66, 35). The time evolution of the ball/balls is diagnosed with dual-axes point-projection radiography. In this poster, we discuss the results of high-resolution three-dimensional radiation-hydrodynamic simulations with the adaptive-mesh-refinement RAGE code of single and multiple balls. Comparisons with data from our August shots will be made.

BP8.00097 Using Hydrodynamic Codes in Modeling of Multi-Interface Diverging Experiments for NIF[1] , M.J. GROSSKOPF, R.P. DRAKE, C.C. KURANZ, University of Michigan, T. PLEWA, N. HEARN, University of Chicago, D. ARNETT, C. MEAKIN, University of Arizona, A.R. MILES, H.F. ROBEY, J.F. HANSEN, B.A. REMINGTON, W. HSING, M.J. EDWARDS, Lawrence Livermore National Laboratory — Using the Omega Laser, researchers studying supernova dynamics have observed the growth of Rayleigh-Taylor instabilities in a high energy density system. The NIF laser hopes to generate the energy needed to expand on these experiments to a diverging system. We report scaling simulations to model the interface dynamics of a multilayered, diverging Rayleigh-Taylor experiment for NIF using a combination of 1D and 2D Hyades, a Lagrangian 3-temperature, 1-fluid hydrodynamic simulation code used within the high energy density physics community, and CALE, a hybrid adaptive Lagrangian-Eulerian code developed at LLNL and used extensively throughout the hydro community. The simulations will assist in the target design process and help choose diagnostics to maximize the information we receive in a particular shot. This will be critical given that early experiments on NIF will get few shots and take a considerable amount of time and money to prepare.

[1] This research was sponsored by LLNL through contract LLNL B56128 and by the NNSA through DOE Research Grant DE-FG52-04NA00064.

BP8.00098 Effect of relaxation and radiation transport on the structure of electro-magnetically driven strong shock waves[1] , KOTARO KONDO, MITSUO NAKAJIMA, TOHRU KAWAMURA, KAZUHIKO HORIOKA, Tokyo Institute of Technology, DEPARTMENT OF ENERGY SCIENCES TEAM — Strong shocks appear in many astrophysical phenomena, such as supernova remnants. Ion-electron relaxation process and radiative transport affect the structure of strong shock waves. Study on these phenomena should contribute to get the well understanding of astrophysical phenomena. We investigate electro-magnetically driven shock in the laboratory experiments. The pulse power device with tapered electrodes can generates a quasi steady and 1-D shock [1], which enables to analyze ion-electron relaxation and radiation processes. The shock Mach number can be up to 250, which correspond to 45 km/s. We will discuss the structure of electro-magnetically driven shock, especially ion-electron relaxation process accompanied with radiation transport, based on experimental results.

[1] K. Kondo, M. Nakajima, T. Kawamura and K. Horioka, Rev. Sci. Instr. **77**, 036104 (2006).

[1] Support from JSPS.

BP8.00099 Laboratory experiments to study supersonic astrophysical flows interacting with clumpy environments , P.A. ROSEN, J.M. FOSTER, AWE, B.H. WILDE, R. COKER, LANL, B.E. BLUE, GA, R.J.R. WILLIAMS, AWE, F. HANSEN, C. SORCE, LLNL, P. HARTIGAN, R. CARVER, J. PALMER, Rice University — A wide variety of objects in the universe drive supersonic outflows through the interstellar medium which is often highly clumpy. These inhomogeneities affect the morphology of the shocks that are generated. The hydrodynamics is difficult to model as the problem is inherently 3D and the clumps are subject to a variety of fluid instabilities as they are accelerated and destroyed by the shock. Over the last two years, we have been carrying out experiments on the University of Rochester's Omega laser to address the interaction of a dense-plasma jet with a localized density perturbation. More recently, we have turned our attention to the interaction of a shock wave with a spherical particle. We use a 1.6-mm diameter, 1.2-mm length Omega hohlraum to drive a composite plastic ablator (which includes bromine to prevent M-band radiation from preheating the experiment). The ablator acts as a "piston" driving a shock into 0.3 g/cc foam containing a 0.5-mm diameter sapphire sphere. We radiograph along two orthogonal lines of sight, using nickel or zinc pinhole-apertured x-ray backlighters, to study the subsequent hydrodynamics. We present initial experimental results and multi-dimensional simulations of the experiment.

BP8.00100 Plasma Jet and Shock Experiments Using High-Power Lasers , YOUICHI SAKAWA, A. OYA, S. DONO, T. KIMURA, N. OZAKI, Y. KURAMITSU, T. KATO, H. NAGATOMO, K. SHIGEMORI, R. KODAMA, T. NORIMATSU, H. TAKABEA, ILE, Osaka Univ., JAPAN, B. LOUPAIS, M. KOENIG, LULI, Ecole Polytechnique, France, J. WAUGH, N. WOOLSEY, Dept. of Physics, York Univ., UK — We investigate laboratory laser-plasma experiments to address questions connected to the formation and collimation of astrophysical jets and shock waves. In particular, we plan to scale our experiments to non-relativistic jets associated with Young Stellar Object. Experiments were performed with Gekko / HIPER laser system (3w, 500 ps, 300 - 750 J, $< 10^{15}$ W/cm^2) at ILE, Osaka Univ. Several types of targets were used; 10 μm thick plane or 600 μm diameter hemisphere CH shell targets with an Au-cone, foam-filled cone targets targets, and hemisphere CH. These targets were used to create plasma jets. In order to produce a shock wave, a He gas jet system was placed on the bottom on the vacuum chamber. The plasma jet and shock were measured with a Mach-Zender interferometry diagnostic, using a probe laser pulse in the transverse direction; an ICCD camera with 200 ps gate time and a S1 streak camera were used. As rear-side diagnostics of self-emission, we used HISAC and SOP for time-evolution measurements of 2-D self-emission profile and temperature, respectively. In all types of the targets, clear jets were observed.

BP8.00101 Hydrodynamic and atomic-kinetic modeling of photoionised neon plasmas , IAIN HALL, TUNAY DURMAZ, ROBERTO MANCINI, Univ. of Nevada, Reno, JIM BAILEY, GREGORY ROCHAU, Sandia Nat. Labs., MICHAEL ROSENBURG, DAVID COHEN, Swarthmore College, IGOR GOLOVKIN, JOSEPH MACFARLANE, Prism Comp. Sciences, MANOLO SHERRILL, JOSEPH ABDALLAH, LANL, ROBERT HEETER, MARK FOORD, SIEGFRIED GLENZER, LLNL — Photoionised plasmas are common in astrophysical environments and in recent years, high resolution spectra from such sources have been recorded by the Chandra and XMM-Newton satellites. These have motivated several recent efforts to understand the atomic-kinetic and radiative characteristics of such plasmas in detail. The Z-pinch facility at the Sandia lab is the most powerful terrestrial source of X-rays and provides an opportunity to produce photoionised plasmas in a well characterised radiation environment. We present modeling work and experimental design considerations for a forthcoming experiment at Sandia in which the X-ray emission from a collapsing Z-pinch will be used to photoionise low density neon contained in a gas cell. View factor calculations were used to evaluate the radiation environment at the gas cell. These were used to design shielding which maximises the contribution of Z-pinch emission to the total X-ray flux incident on the gas cell. The Helios-CR code was used to examine the hydrodynamic characteristics of the gas cell, in particular looking at the heating, temperature and ionisation of the neon and the absorption of radiation by the plastic walls enclosing the gas.

BP8.00102 Chaotic magnetic fields due to asymmetric current configurations - application to cross-field diffusion of particles in cosmic rays[1] , B. DASGUPTA, IGPP, UC-Riverside, A.K. RAM, PSFC, MIT — The observed cross-field diffusion of charged particles in cosmic ray transport is assumed to be due to chaotic nature of the interplanetary/intergalactic magnetic fields. The particles are accelerated and energized by the temporal fluctuations of the magnetic field. The generation of chaotic magnetic fields is *ad hoc* and the characteristics of the fields are chosen to satisfy the observations. We consider simple current configurations consisting of circular loops and straight wires that generate asymmetric, nonlinear, steady-state magnetic fields in three spatial dimensions. These magnetic fields are completely deterministic, and, for certain range of parameters, chaotic. We will present analytical and numerical studies on the generation of chaotic magnetic fields and the nature of these fields. The motion of charged particles in these magnetic fields can be described by the Lorentz equation. An analysis of the particle motion will also be presented. A particle moving in a chaotic magnetic field superposed on a uniform background magnetic field is found to undergo spatial transport. This shows that chaotic magnetic fields can produce cross-field diffusion.

[1]Work supported by DoE grant DE-FG02-91ER-54109 and NASA grant NNG-4GF83G.

BP8.00103 Dynamics of Cosmic Ray acceleration in a modified shock[1] , ALEXANDER PUSHKIN, MIKHAIL MALKOV, PATRICK DIAMOND, University of California San Diego — Backreaction of accelerated cosmic rays (CRs) on the structure of the shock which supports their acceleration results in bifurcation of stationary solutions. Therefore the process of nonlinear shock acceleration of CRs in strong astrophysical shocks cannot be fully understood within a steady state approach. We analyze stability and evolution of the structure of a nonlinearly modified shock in the framework of a zero-dimensional time dependent system of ODEs. The system is derived from the convection-diffusion equation which describes the acceleration and transport of cosmic rays coupled to the plasma flow profile near the shock. The main variables of the resulting system are the shock strength (in form of subshock and precursor compression ratios) and the maximum CR energy. A self-consistent dependence of the injection rate on the subshock compression is included. This study enables: (i) selection of possible acceleration regimes (ii) analysis of stability of different steady state solutions (iii) time dependent description of the dynamics of coupled CR-shock system.

[1]NASA, US DoE

BP8.00104 Relativistic MHD Jets and Their Interactions with the Intra-cluster Medium , HUI LI, MASA NAKAMURA, SHENGTAI LI, LANL, HAO XU, LANL/UCSD — We present the formulation of relativistic MHD flows, likely occurring in the environment of accretion onto supermassive black holes. Three-dimensional relativistic MHD simulations will be presented on how the energy outflow will partition among different physical components and on the collimation and stability of such systems. The interaction between such flows with their environment, e.g., the intra-cluster medium, will be discussed.

BP8.00105 Deformation of a magnetized plasma jet upon collision with a neutral gas cloud[1] , A.L. MOSER, P.M. BELLAN, Caltech — The Caltech spheromak formation and astrophysical jet simulation experiment uses a coplanar spheromak gun with magnetically linked concentric electrodes. This geometry and the electric field applied between the electrodes provide an analog to the accretion disk environment and allow production of collimated plasma jets similar to those found in astrophysical settings. The experiment has been used to study the evolution of a plasma jet when it collides with a localized neutral gas cloud. The experiment produces a collimated, magnetized dense plasma jet that propagates through a very low pressure environment before colliding with a high density neutral gas cloud. A high speed camera and a magnetic probe array characterize the physical and magnetic field structure of the plasma jet with and without a target gas cloud present.

[1]Supported by USDOE

BP8.00106 MHD kink instability driven by differential rotation , CHRISTOPHER CAREY, CARL SOVINEC, SEBASTIAN HEINZ, University of Wisconsin — Recent observations of extragalactic outflows from active galactic nuclei suggest that some of these jets maintain a large scale helical magnetic structure [1]. The kink instability is known to create similar magnetic structures in laboratory plasmas. Thus, extragalactic jets may resemble a screw pinch topology and be susceptible to the current driven kink instability. We are conducting numerical MHD simulations which will address the issues of collimation and stability of the extragalactic jet system. In these simulations an initial seed field is twisted by a differentially rotating flow boundary condition. Three dimensional nonlinear calculations show that the magnetic column produced is kink unstable and that the instability saturates to a helical magnetic structure. The kink instability in the numerical system leads to conversion of the toroidal magnetic flux, which is injected by the differentially rotating boundary, to poloidal magnetic flux. Examination of this flux conversion process could lead to a better understanding of how the jet distributes magnetic energy to the medium which surrounds it. A synthetic diagnostic has been implemented for calculating the synchrotron emission of the numerical jet. This synthetic synchrotron emission is compared to observations of actual extragalactic jet systems.
[1] D.M. Worrall, M. Birkinshaw, et. al., Mon. Not. R. Astron. Soc., May, 2007

BP8.00107 Experimental and Numerical Studies of Magnetic Bubble Expansion as a Model for Extra-Galactic Radio Lobes[1] , A.G. LYNN, Y. ZHANG, University of New Mexico, S.C. HSU, H. LI, W. LI, Los Alamos National Laboratory, M. GILMORE, CHRISTOPHER WATTS, University of New Mexico — Recent work in plasma astrophysics has suggested that magnetic energy features prominently in the large-scale evolution of active galaxies. The Plasma Bubble Expansion Experiment (PBEX) will conduct laboratory experiments and coordinated numerical modeling to address outstanding nonlinear plasma physics issues related to how magnetic energy and helicity carried by extra-galactic jets interacts with the intergalactic medium to form extra-galactic radio lobe structures. Experiments will be conducted in the 4 meter long, 50 cm diameter HELCAT linear plasma device at UNM. A new pulsed coaxial gun will form and inject magnetized plasma bubbles into a lower pressure background plasma formed by the helicon and/or hot cathode source in HELCAT. Experimental parameters will be adjusted so that important dimensionless parameters are relevant to the astrophysical context. Preliminary magnetic probe measurements and MHD modeling will be presented.

[1]Supported by NSF-AST/DOE and LANL LDRD

BP8.00108 Instabilities and Structure Evolution in Radiative Shocks , F.W. DOSS, R.P. DRAKE, A.J. VISCO, C.C. KURANZ, M.J. GROSSKOPF, University of Michigan, A.B. REIGHARD, Lawrence Livermore National Laboratory, J. KNAUER, Laboratory for Laser Energetics — Radiative shocks, systems in which radiation transport across the shock front contributes substantially to the properties and dynamics of the shock, occur frequently in astrophysical systems, motivating our high-energy-density experiments. Recent laser-driven experiments have produced collapsed shocks by launching 10-20 μm drive disks of Be into shock tubes of Xe gas at atmospheric pressure. This method produces strongly radiative shocks at well over 100 km/sec. Experiments using x-ray pinhole radiography of collapsed radiative shocks have revealed evidence of structure evolution, perhaps through instability mechanisms. Recent experiments provided simultaneous normal and oblique data. Theoretical work related to structure growth will also be reported. This research was sponsored by the NNSA through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA0064, and the NNSA Stewardship Science Graduate Fellowship.

BP8.00109 DYNAMOS AND HELIOPHYSICAL PLASMA PHYSICS —

BP8.00110 Overview of Recent Upgrades to the Madison Dynamo Experiment , ELLIOT KAPLAN, CARY FOREST, ROCH KENDRICK, CARLOS PARADA, ZANE TAYLOR, Univ. of Wisc.–Madison, MARK NORNBERG, PPPL, ERIK SPENCE, ETH–Zurich — The Madison Dynamo Experiment is designed to function as a simply-connected, homogeneous dynamo. A turbulent flow of liquid sodium is driven by two counter-rotating impellers in a one-meter-diameter sphere. The experiment is presently undergoing upgrades to it's magnetic diagnostics and seed field coils to better refine the measurement of turbulence driven currents. A high current amplifier, to drive the experiment's seed magnetic field coils, is under development that will be able to generate a >200 gauss sinusoidal magnetic field in the .1-5 Hz frequency band. The current wave form is generated by applying pulse-width-modulated square waves to a set of four IGBT switches in an H Bridge configuration which allows the current to flow in either direction through the external field coils. The duty cycle is determined through one of two methods: An analog circuit generates a reference sine wave and a modulating triangle wave in an intersective PWM circuit; a Labview Realtime control that uses a PID feedback loop to calculate the duty cycle. This is replacing the present system of a single IGBT turning on a DC current through the coils. The primary physics goal for this hardware is to measure the electrical skin depth of large scale magnetic perturbation and unravel the nature of the turbulent resistivity of the experiment.

BP8.00111 Direct Numerical Simulation of Mechanically Driven Turbulent Dynamos in Spherical Geometry , KLAUS REUTER, FRANK JENKO, Max-Planck-Institut fuer Plasmaphysik, CARY FOREST, ADAM BAYLISS, University of Wisconsin-Madison — A parallel version of a nonlinear pseudo-spectral MHD code for the simulation of liquid metal dynamos in spherical geometry was developed using a domain decomposition technique. The parallel code exhibits ideal scaling going up to 8 CPUs on shared-memory machines. At 16 CPUs, it still achieves efficient speedups between 14 and nearly 16. Given today's computational speed, it is now possible to resolve fluid Reynolds numbers of $\mathrm{Re} \approx 4000$ in the simulations, whereas previous serial computations were limited to $\mathrm{Re} \approx 1500$. Direct numerical simulations are performed to explore the dynamo threshold $\mathrm{Rm}_{\mathrm{crit}}$ (the critical magnetic Reynolds number) in Re-Rm-space for the flow profile of the Madison Dynamo Experiment. The shape of $\mathrm{Rm}_{\mathrm{crit}}$ has been determined up to $\mathrm{Re} \approx 3000$. Furthermore, the code was adapted to model the driving of a new generation of dynamo experiment using plasma instead of liquid metal. By employing pure toroidal driving in two thin counter-rotating hemispherical shells along the walls, numerical simulations show that the system reaches a quasi-stationary state with a self-excited magnetic field.

BP8.00112 Optimization of flows in the Madison Dynamo Experiment , N.Z. TAYLOR, C.B. FOREST, N.S. HAEHN, E.J. KAPLAN, R.D. KENDRICK, C.A. PARADA, C.R. WEBER, University of Wisconsin-Madison, M.D. NORNBERG, PPPL, E.J. SPENCE, ETH Zurich — In the Madison Dynamo Experiment two counter-rotating impellers in a one meter-diameter sphere drive turbulent flows of liquid sodium. One goal of the experiment is to observe the spontaneous onset of a large scale dynamo in the presence of background turbulence. The time-averaged flows created by the impellers are expected to be dynamos (assuming that the time-averaged flows are laminar). The role of the fluctuations is expected to increase the threshold for self-excitation. To observe a dynamo in the experiment, two sets of optimizations are being implemented. First, the mean-flow is being optimized using a combination of a Computational Fluid Dynamics (CFD) simulation of the experiment coupled with an eigenmode code. The CFD simulation predicts the velocity field due to the addition of vanes mounted on the outer wall to change the overall pitch of the mean flow. The vane pitch has been optimized by minimizing the critical magnetic Reynolds number. The second optimization is to reduce the overall turbulent fluctuation amplitude by introducing an equatorial baffle to partially separate the two hemispheres of the experiment. These optimizations are in the process of being tested in a water version of the experiment and are being implemented in the sodium experiment.

BP8.00113 A Plasma, Magnetorotational Instability Experiment , C. COLLINS, C.B. FOREST, R. KENDRICK, University of Wisconsin, Madison, A. SELTZMAN, NUF, Georgia Institute of Technology — A new experiment is underway at the University of Wisconsin to investigate the magnetorotational instability in a plasma. Magnetorotational instability (MRI) is a likely mechanism that could account for the observed accretion rates in astrophysical objects. The instability occurs when a weak magnetic field is present, so that tension in perturbed field lines transfers angular momentum outward while mass moves towards the center. In the Plasma Dynamo Experiment Prototype, a cylindrical, axisymmetric, ring cusp confinement geometry is used to produce a large unmagnetized plasma, confined by a highly localized magnetic field at the plasma boundary. The plasma is stirred by a novel axisymmetric electrode set that can control the rotation (angular momentum profile). The feasibility of observing the MRI will be discussed and initial results from a protoype experiment will be presented.

BP8.00114 A Plasma Dynamo Experiment based upon Ring Cusp Confinement and Electrostatic Stirring , CARY FOREST, UW Madison, GENNADY FIKSEL, NOAH HERSHKOWITZ, ROCH KENDRICK, STEVE COWLEY, UCLA, ERIK SPENCE, ETH Zurich — A new plasma experiment to investigate the self-generation of magnetic fields is proposed. The experiment consists of a spherical vacuum chamber with a series of permanent magnetics, with electrically insulated pole faces, in a ring cusp geometry (poles facing inward with alternating polarity along the vessel wall). The resulting field is axisymmetric and decays quickly away from the walls providing a large, magnetic field free region in the central region of the device. To stir the plasma, cathodes positioned between the magnet rings are biased such that the resulting electric field induces plasma rotation through the ExB drift. The flow drive principle is quite general and by controlling the poloidal profile of the toroidal rotation, high magnetic Reynolds number plasmas flows can in principle be generated that result in magnetic field self-generation or plasma flows unstable to the magnetorotational instability. Use of a plasma for such an experiment may allow the magnetic Reynolds number (the dimensionless parameter governing self-excitation of magnetic fields) to be approximately a factor of 10 larger than in liquid metal experiments and will be the first experiment to investigate self-excited dynamos in a plasma,the state of matter that makes up most naturally occuring astrophysical dynamos.

BP8.00115 Measuring and imaging bulk flows in laboratory plasma loops[1] , E.V. STENSON, P.M. BELLAN, California Institute of Technology — Arched plasmas similar to solar coronal loops are made in the lab by means of a magnetized plasma gun. These plasma structures are created in a process resembling that used to make spheromaks, exhibit behavior that is also seen in the sun, and demonstrate some very general flow phenomena. It has been proposed that in a current-carrying flux tube with nonuniform cross-section, plasma jets flow from more constricted to less constricted regions (P. M. Bellan, Phys. Plasmas 10, 1999 (2003)). By making arched plasmas from two different gas species - one at each of the two footpoints of the arch - we see that this is indeed the case. High-speed imaging with optical filters reveals a jet emanating from each footpoint. With velocities on the order of the Alfven speed, these jets move much faster than both the sound speed of the neutral gas and the thermal velocity of the ions. The technique of using two gases will next be used for experiments wherein two adjacent plasma arches merge. Each will be made of a different gas, so that the process by which the two combine can be resolved.

[1]supported by USDOE and AFOSR

BP8.00116 Observing Energetic Bursts in the Caltech Solar Coronal Loop Simulation[1] , R.J. PERKINS, G.S. YUN, P.M. BELLAN, California Institute of Technology — X-ray bursts have previously been observed in a solar coronal loop experiment (J.F. Hansen, S.K.P. Tripathi, and P.M. Bellan, Phys. Plasma 2, 3177(2004)) where two parallel plasma-filled flux tubes merged in either a co-helicity or counter-helicity arrangement. These x-ray bursts were observed with a set of x-ray photo-diodes. We are developing means to observe these bursts with additional diagnostics. A low cost photo-electric detector was thoroughly tested on a test chamber using a xenon flashlamp. The detector utilizes the low work function of magnesium to measure ultraviolet radiation. A photo-scintillator is being developed to detect hard x-ray emission down to 10 keV. A smaller photo-scintillator was previously constructed and used in the Caltech spheromak experiment; we have enlarged the scintillating volume in hopes of increasing sensitivity. Finally, in a single loop experiment, spectroscopic measurements detect the onset of oxygen impurity lines at the loop apex; the onset is simultaneous with the formation of a bright spot at the same location. Future spectroscopic measurements are planned to investigate the apex region during merging.

[1]Sponsored by USDOE

BP8.00117 Measurement of Electrical Currents in the Solar Corona , STEVEN SPANGLER, University of Iowa — Some theories for heating of the solar corona invoke Joule heating by electrical currents. Observations of spatially-extended radio sources through the corona show times when there is a difference in the Faraday rotation between two lines of sight separated by about 33,000 km in the corona. Ampere's Law is used to relate these observations to the presence of electrical current flowing between the two lines of sight. I infer a current of 2.5×10^9 Amperes in the case of the strongest signal, and a current of 2.3×10^8 Amperes in another, marginally significant detection. A model of coronal current sheets is used to interpret the current measurements, and estimate the volumetric heating rate due to Joule dissipation. The model uses the Spitzer resistivity. The model heating rate is approximately 6 orders of magnitude less than independent, observational estimates in the relevant part of the corona. Either the currents detected play a negligible role in coronal heating, or the effective resistivity in the corona is 6 orders of magnitude larger than the Spitzer value.

BP8.00118 Lagrangian Simulations of Current Sheet Formation During Relaxation of an Unstable Line-Tied Equilibrium[1] , LIWEI LIN, C.S. NG, A. BHATTACHARJEE, Center for Integrated Computation and Analysis of Reconnection and Turbulence, Center for Magnetic Self-Organization, University of New Hampshire — Our recent theory, based on reduced MHD equations, predicts the formation of current sheets (tangential discontinuities) in an ideal line-tied plasma when an unstable equilibrium relaxes to a state of minimum energy [C. S. Ng and A. Bhattacharjee, Phys. Plasmas **5**, 4028 (1998)]. This mechanism has important implications for the heating of the solar corona, first envisioned by E. N. Parker. Testing of this prediction using conventional Eulerian simulations is subjected to the intrinsic numerical difficulty that the magnetic field line mapping is not kept fixed explicitly, as required by the line-tied condition. In fact, field line mapping can change substantially by reconnection due to numerical resistivity. To overcome this obstacle, we have developed a Lagrangian relaxation algorithm to simulate the evolution of an unstable equilibrium by following the movement of magnetic field lines explicitly. Preliminary simulation results will be presented.

[1]This research is supported by NSF grant AST-0434322, NASA, and DOE.

BP8.00119 Solar Coronal Heating and Magnetic Energy Build-Up in a Tectonics Model[1] , M. GILSON, C.S. NG, A. BHATTACHARJEE, Center for Integrated Computation and Analysis of Reconnection and Turbulence and Center for Magnetic Self-Organization, University of New Hampshire — Observations from SOHO and TRACE have shown that the solar surface is covered with a so-called "magnetic carpet," in which small-scale magnetic flux loops are continually emerging and interacting. The magnetic flux at the photosphere is thus being replaced in every 10-40 hours. This magnetic carpet has important implications for the problem of coronal heating. We have extended a tectonics model of coronal heating [E. Priest, J. Heyvaerts and A. Title, Astrophys. J. **576**, 533 (2002)] and shown, based on analysis and numerical simulations, that the heating rate is independent of the Lundquist number as well as the photospheric coherence time, if the magnetic footpoints are subject to random photospheric motion. We have also found that magnetic energy can be built up to a statistically high level before the energy is released by some mechanisms, such as instabilities and/or magnetic reconnection. We have also shown that even if such processes limit the build-up of magnetic energy, the overall heating rate is still independent of the Lundquist number.

[1]This research is supported by a NSF grant AST-0434322, and a NASA grant.

BP8.00120 The Effect of Magnetic Turbulence Energy Spectral Scaling on the Heating of the Solar Wind[1] , D. MUNSI, C.S. NG, A. BHATTACHARJEE, P.A. ISENBERG, Center for Integrated Computation and Analysis of Reconnection and Turbulence, Center for Magnetic Self-Organization, University of New Hampshire — Recently, a phenomenological solar wind heating model based on a turbulent energy cascade prescribed by the Kolmogorov theory has produced reasonably good agreement with observations on proton temperatures out to distances of the order of 70 AU, provided the effect of turbulence generation due to pickup ions is included in the model. Without the inclusion of pickup ions, the Kolmogorov scaling law appears to predict a proton temperature profile that drops off too rapidly with radial distance from the Sun. In this study, we have incorporated in the heating model the energy cascade rate based on Iroshnikov-Kraichnan (IK) scaling, derivable from incompressible magnetohydrodynamics. We show that the model can produce significantly higher proton temperatures, within the range of observations, with or without the inclusion of pickup ions. Moreover, the turbulence correlation lengths prescribed by IK scaling seem to follow better the trend of observations, as compared with previous results based on Kolmogorov scaling, which showed a qualitatively different trend.

[1]This work is supported by NASA, DOE and NSF.

BP8.00121 Alignment of Velocity and Magnetic Fluctuations in Simulations of Anisotropic MHD Turbulence[1] , C.S. NG, A. BHATTACHARJEE, Center for Integrated Computation and Analysis of Reconnection and Turbulence (CICART), University of New Hampshire, Durham, NH 03824 — There has been recent theoretical interest in the effect of the alignment of velocity and magnetic fluctuations in three-dimensional (3D) MHD turbulence with a large-scale magnetic field [Boldyrev 2005, 2006]. This theory predicts that the angle θ between the velocity and magnetic fluctuation vectors has a scaling of $\theta \propto \lambda^{1/4}$, where λ is the spatial scale of the fluctuations. There have also been simulations on 3D forced MHD turbulence that supports this prediction [Mason *et al.* 2006, 2007]. The scaling has also been tested against observations of solar wind turbulence [Podesta *et al.* 2007]. We report here simulation results based on decaying 2D turbulence. The scaling of $\theta \propto \lambda^{1/4}$ and Iroshnikov-Kraichnan scaling has also been observed within a range of time interval and spatial scales, despite the fact that Boldyrev's theory was developed for fully 3D turbulence in the presence of a strong external field. As the external field is reduced in magnitude and becomes comparable to the magnitude of magnetic fluctuations or lower, the scale-dependent alignment is weakened. Implications for observations of solar wind turbulence will be discussed.

[1]This work is supported by NASA.

BP8.00122 Scattering of Suprathermal Electrons in the Solar Wind: Particle-in-Cell Simulations , S. PETER GARY, SHINJI SAITO, Los Alamos National Laboratory — Properties of the narrow, magnetic-field-aligned strahl electron velocity distributions are sensitive indicators of collisionless processes in the solar wind. Three distinct signatures have been observed in the characteristics of this suprathermal (70 eV < Energy < 1 keV) component: 1) Pitch-angle widths that decrease with increasing energy, 2) Pitch-angle widths that increase with increasing energy, and 3) Pitch-angle widths that have a distinct maximum as a function of energy. This presentation describes results from particle-in-cell simulations which have used three different sources of enhanced fluctuations to demonstrate how each of these signatures can arise. Signature 1) is well-known as being due to scattering by Coulomb collisions, but the simulations have shown that it may also arise as a consequence of scattering by the whistler anisotropy instability driven by a $T_\perp/T_\| > 1$ condition on the electron core component. Signature 2) has been shown by quasilinear theory to arise due to scattering by a broadband spectrum of whistler fluctuations; our simulations confirm that conclusion. Signature 3) arises from scattering due to the electrostatic electron/electron instability. The simulations demonstrate how the latter two signatures change with various plasma parameters.

BP8.00123 Remote Measurements of Ion Temperatures in the Terrestrial Magnetotail , AMY KEESEE, EARL SCIME, West Virginia University — The plasma in the terrestrial magnetotail plays a central role in magnetospheric storms and substorms. Reconnection in the magnetotail yields flows in the tailward and earthward directions, redistribution of energetic particles throughout the inner magnetosphere, and possibly direct ion heating by waves. The magnetotail, out to 30-40 Earth radii, lies in the field of view of the instruments on the Imager for Magnetopause-to-Aurora Global Explorer (IMAGE) satellite when the spacecraft is in a favorable position in its orbit. *McComas et al.* (2002) showed that the Medium Energetic Neutral Atom (MENA) imager onboard IMAGE measures significant neutral flux from this region during periods of intense magnetospheric activity, i.e., when the plasmasheet density is enhanced by plasma injections from the solar wind and ionospheric outflows. We present remote ion temperature measurements calculated from MENA neutral flux measurements from 1 – 60 Earth radii during a substorm on 4-5 October 2000 (DOY 278-279). During the evolution of the substorm, a wave of increasing ion temperature appears to propagate earthward through the magnetotail.

BP8.00124 Hybrid Simulations of Mini Magnetospheres in the Laboratory , LUIS GARGATE, Instituto Superior Tecnico, Portugal, RUTH BAMFORD, ROBERT BINGHAM, Rutherford Appleton Laboratory, UK, RICARDO FONSECA, LUIS SILVA, Instituto Superior Tecnico, Portugal — We use a massively parallel 3D hybrid particle code, dHybrid, to simulate the deflection of plasma beams by a dipole like magnetic field in a laboratory environment. Dipole magnetic fields, along with a plasma injection source to inflate the magnetic field, are now being studied as means of deflecting solar wind and Energetic Particles away from spacecrafts [1,2,3]. We have considered three setups, consistent with the experiments, with a plasma beam fired at i) a dipole field with no plasma injection, ii) a plasma injection source with no dipole field and iii) a dipole field with a plasma injection source. The hybrid simulations help understand the relevant physical phenomena, and enable extrapolation to space plasma scenarios, where setups are similar but plasma parameters differ significantly. The simulation results consistently show the plasma beam being deflected by the dipole field, in the first scenario, with the deflecting distance determined by the magnetic field intensities. The other two scenarios are also studied via hybrid simulations and the main physical differences between setups are highlighted. Comparisons with experimental results are discussed. [1] D. Winske et al, Phys. Plasmas 12 (2005) [2] Hai-Bin Tang et al, Phys. Plasmas 14 (2007) [3] http://www.ukssdc.ac.uk/twiki/bin/viewauth/Minimag/WebHome

BP8.00125 3D hybrid simulation of the Titan's plasma environment , ALEXANDER LIPATOV, GEST Center UMBC, EDWARD SITTLER JR., RICHARD HARTLE, NASA GSFC — Titan plays an important role as a simulation laboratory for multiscale kinetic plasma processes which are key processes in space and laboratory plasmas. A development of multiscale combined numerical methods allows us to use more realistic plasma models at Titan. In this report, we describe a Particle-Ion–Fluid-Ion–Fluid–Electron method of kinetic ion-neutral simulation code. This method takes into account charge-exchange and photoionization processes. The model of atmosphere of Titan was based on a paper by Sittler, Hartle, Vinas et al., [2005]. The background ions H^+, O^+ and pickup ions H_2^+, CH_4^+ and N_2^+ are described in a kinetic approximation, where the electrons are approximated as a fluid. In this report we study the coupling between background ions and pickup ions on the multiple space scales determined by the ion gyroradiis. The first results of such a simulation of the dynamics of ions near Titan are discussed in this report and compared with recent measurements made by the Cassini Plasma Spectrometer (CAPS, [Hartle, Sittler et al., 2006]).
E C Sittler Jr., R E Hartle, A F Vinas, R E Johnson, H T Smith and I Mueller-Wodarg, J. Geophys. Res., 110, A09302, 2005.
R E Hartle, E C Sittler, F M Neubauer, R E Johnson, et al., Planet. Space Sci., 54, 1211, 2006.

BP8.00126 Simulations of plasmas pentrating magnetic barriers[1] , HERBERT GUNELL, West Virginia University, TOMAS HURTIG, Swedish Defence Research Agency, MARK KOEPKE, West Virginia University, NILS BRENNING, Royal Institute of Technology, Stockholm, HANS NILSSON, Swedish Institute of Space Physics — Perturbed currents perpendicular to the magnetic are generated by plasma motions in which the equilibrium magnetic field (and the corresponding equilibrium currents) are compressed, stretched, and deformed. One example of this is the Earth's magnetopause with its ever-present equilibrium transverse currents and its strong perturbations. Experiments have recently been performed using a plasma gun to shoot a plasma at a magnetic barrier (Brenning, et al., PoP, 2005). It was found that, at a critical drift that is about 2-3 times the ion thermal speed, non-linear oscillations in the lower hybrid range give rise to a resistivity which is at least 200-300 times the Spitzer resistivity. We present simulations of the above scenario for different values of the plasma kinetic energy density. We find waves with frequencies on the order of the plasma frequency. These waves contribute to the electron heating that has been observed both in the experiments and in previous simulations (Hurtig, et al., PoP, 2003).

[1]Supported by the U.S. Department of Energy, and by the National Science Foundation.

BP8.00127 Spectral Characteristics of Weakly-Collisional Stationary Alfvén Waves[1] , S.M. FINNEGAN, M.E. KOEPKE, West Virginia University, D.J. KNUDSEN, University of Calgary — The spectral properties of weakly-collisional stationary Alfvén (StA) waves are presented. StA waves, stationary electromagnetic structures generated by plasma flow across magnetic field-aligned current sheets, have a stationary parallel electric field structure that can energize electrons along magnetic field lines [Knudsen, **JGR** (1996)]. Knudsen's model has been generalized to include collisional and thermal effects. Ion-neutral collisions are shown to introduce long-wavelength **k**-space spectral features which produce "quasi-dc" field-aligned electron acceleration for both StIA and stationary kinetic Alfvén (StKA) waves. Ion- neutral collisions are also shown to broaden spectral features, without shifting the dominant perpendicular wavenumber for StIA waves. For StKA waves both ion-neutral and electron collisions broaden spectral features and increase the number of Fourier components. StIA wave spectra and spatial scales are consistent with measurements of dispersive Alfvén wave turbulence observed by various rocket and satellite missions.

[1]Work supported by NSF-PHY-0613238 and DOE.

BP8.00128 Generation of Lower Hybrid Waves in an Oxygen Dominated Plasma[1] , MANISH MITHAIWALA, NRL Plasma Physics Division, LEONID RUDAKOV, Icarus Research Inc., GURUDAS GANGULI, NRL Plasma Physics Division — A previous work considered the generation of ULF waves in the inner Magnetosphere due to a heavy ion ring distribution such as Lithium, Cesium or Barium [Ganguli et al., 2007]. We extend this analysis by considering the generation of Lower-hybrid waves in an Oxygen dominated plasma at R∼500km due to a Barium ion ring distribution. In this situation it is possible to generate ion-Bernstein modes or Lower-hybrid waves. We demonstrate the criteria in which Lower-hybrid waves are produced. The growth rate is found to be strongly dependent on the ion thermal velocity. For a broad range of parameters the growth rate $\gamma > \Omega_{Ba}$ so that the Barium ions are considered to be unmagnetized which simplifies the analysis. The analysis is compared with space experiments done several decades ago. Ganguli, G., L. Rudakov, M. Mithaiwala, and K. Papadopoulos (2007), Generation and evolution of intense ion cyclotron turbulence by artificial plasma cloud in the magnetosphere, *J. Geophys. Res.*, 112, A06231, doi:10.1029/2006JA012162.

[1]Supported by ONR.

BP8.00129 Laboratory experiments to investigate auroral cyclotron emission processes , SANDRA MCCONVILLE, KEVIN RONALD, ALAN PHELPS, DAVID SPEIRS, KAREN GILLESPIE, ADRIAN CROSS, COLIN WHYTE, CRAIG ROBERTSON, University of Strathclyde, ROBERT BINGHAM, BARRY KELLETT, STFC, Rutherford Appleton Laboratory, IRENA VORGUL, ALAN CAIRNS, University of St Andrews — In the auroral regions of the Earth's magnetosphere, particles are accelerated downwards into an increasing magnetic field. Magnetic compression leads to the formation of a velocity distribution in the shape of a horseshoe due to conservation of the magnetic moment. Kilometric radiation is observed in association with this process, polarised in the X-mode. The RF output power has been estimated at 10^7-10^9W, corresponding to a beam-wave conversion efficiency of 1-2%. A cyclotron maser instability driven by the horseshoe distribution is thought to be the source of this **A**uroral **K**ilometric **R**adiation (AKR). A scaled laboratory experiment was created, to simulate this naturally occurring phenomenon. Measurements of the radiation conversion efficiency, mode and spectral content were obtained and seen to be in close agreement with numerical predictions and also with satellite observations in the magnetosphere. The experiment is currently being modified by introducing a background plasma to give a better representation of the natural environment. The latest results of this modification shall be presented.

BP8.00130 Ionospheric Interaction Experiments With Gigawatts , J.P. SHEERIN, J.M. GERRES, M.E. BACON, Eastern Michigan Univ., B.J. WATKINS, W.A. BRISTOW, U. Alaska-Fairbanks, S.I. OYAMA, Nagoya U., C.J. HEINSELMAN, SRI, K.M. GROVES, AFRL — High power HF transmitters have induced a number of plasma instabilities in the interaction region of overdense ionospheric plasma. We report results from the first such experiments to use over one gigawatt of HF power (ERP) in comprehensive studies of strong Langmuir turbulence (SLT) and particle acceleration. Among the effects observed and studied are: SLT spectra including the outshifted plasma line or free-mode, appearance of a short timescale ponderomotive overshoot effect, artificial field-aligned irregularities (AFAI), the aspect angle dependence of the intensity of the plasma line, and suprathermal electrons. We explore the observed magnetic-zenith effect of enhanced turbulence backscatter with the HF pump wave directed up the field line. Experimental results are compared to previous high latitude experiments and predictions from recent modeling efforts.

Monday, November 12, 2007 2:00PM - 5:00PM –
Session CI1 Turbulence, Transport, and Laser Plasmas Rosen Centre Hotel Junior Ballroom

2:00PM CI1.00001 Reduced kinetic descriptions of weakly driven plasma waves[1] , RYAN LINDBERG, University of California, Berkeley — We present a model of kinetic effects in Langmuir wave dynamics using a nonlinear distribution function that includes particle separatrix crossing and self-consistent electrostatic evolution. This model is based on the adiabatic motion of the particles in the wave, and uses the fundamental frequency, its harmonics, and a nearly uniform electric field to describe BGK-type Langmuir waves over a wide range of temperatures ($0.1 \leq k\lambda_D \leq 0.4$). This asymptotic distribution function yields a nonlinear frequency shift of the Langmuir wave that agrees well with Vlasov simulations, and can furthermore be used to determine the electrostatic energy required to develop the phase-mixed, asymptotic state. Energy conservation is used in conjunction with our kinetic theory results to build a simplified model of nonlinear Landau-type damping. The resulting nonlinear, dynamic frequency shift and damping can be used in an extended three-wave type model of driven Langmuir waves, and we discuss comparisons of this model to Vlasov simulations in the context of Raman backscatter.

[1]With A.E. Charman and J.S. Wurtele. Supported by University Education Partnership Program through LLNL and DOE grant No. DE-FG02-04ER41289

2:30PM CI1.00002 Fluid theory of magnetized plasma dynamics at low collisionality[1] , J.J. RAMOS, Massachusetts Institute of Technology — A general fluid moment formalism for magnetized plasmas in a broadly defined low-collisionality regime [1] is presented. This analysis includes collisional terms based on full Fokker-Plank operators for far-from-Maxwellian distribution functions. It is also valid for any magnetic geometry and for fully electromagnetic nonlinear dynamics with arbitrarily large fluctuation amplitudes. Upon asymptotic expansion in the small ratio between the ion Larmor radius and the shortest macroscopic length scale in the absence of small scale turbulence, two-fluid finite-Larmor-radius systems applicable to macroscopic dynamical evolution on either sonic or diamagnetic drift time scales are obtained. In particular, first significant order FLR equations for the stress tensors and the heat fluxes are given, including a discussion of the collisional terms that need be retained and of the closure terms that need be determined kinetically. With a subsidiary small-parallel-gradient ordering for large-aspect-ratio toroidal plasmas in a strong but weakly inhomogeneous magnetic field, a new reduced two-fluid system is derived, taking into account all the diamagnetic effects associated with arbitrary density and anisotropic temperature gradients.
[1] J.J. Ramos, Phys. Plasmas 14, 052506 (2007).

[1]Work supported by the U.S. Department of Energy.

3:00PM CI1.00003 Turbulent transport via wave-particle decorrelation in collisionless plasmas[1]
, ZHIHONG LIN, University of California, Irvine — Understanding the transport mechanism of anisotropic turbulence in collisionless magnetized plasmas is both a fundamental physics issue and a necessary step for projecting confinement properties of next-generation fusion reactors such as the International Thermonuclear Experimental Reactor (ITER). To delineate the role of fluid convection vs. kinetic scattering in turbulent transport, we study the electron heat transport arises from the nonlinear wave-particle interaction for the parallel resonance of the electron temperature gradient mode and for the precessional resonance in collisionless trapped electron mode in large scale kinetic simulations using the gyrokinetic toroidal code, GTC [Lin et al, Science 281, 1835 (1998)]. We found that wave-particle decorrelation is the dominant mechanism responsible for the electron heat transport driven by the electron temperature gradient (ETG) turbulence characterized by radial streamers. The radial transport is driven by the local fluctuation intensity and the phase-space island overlapping leads to a diffusive process with a time scale close to the wave-particle decorrelation time associated with the spectral width of the fluctuations. The kinetic time scales relevant to the transport process are much shorter than the fluid turbulence auto-correlation time, eddy turnover time, and linear growth time. Therefore, the extrapolation of the transport level from present-day experiments to future larger devices could be over-pessimistic, if the simplistic mixing length argument is invoked with the streamer length as the random walk spatial step size and the fluid time scale as the time step size. The mechanism of electron heat transport in collisionless trapped electron mode (CTEM) turbulence through de-tuning of precessional resonance will also be reported.

[1]In collaboration with Y. Nishimura, I. Holod, W. L. Zhang, Y. Xiao, L. Chen, P. H. Diamond, T. S. Hahm, S. Ethier, S. Klasky, F. Zonca. Work supported by DOE SciDAC GPS Center

3:30PM CI1.00004 Experimental investigation of blob physics in the TORPEX toroidal plasma
, IVO FURNO, Centre de Recherches en Physique des Plasmas-Ecole Polytechnique Fédérale de Lausanne, Association EURATOM-Confédération Suisse — Extensive experimental data from tokamaks, stellarators, reversed field pinches and basic linear devices reveal that particle and energy transport in the Scrape-Off-Layer is mostly non-diffusive and associated with the intermittent propagation of blobs. These are poloidally-localized regions extending along the field lines where the plasma pressure is enhanced compared to the surrounding plasma. Significant advances in understanding the mechanism for blob generation and the associated turbulent transport are achieved in the TORPEX toroidal device (R=1m, a=0.2m) using an experimental setup in which blobs are produced and diagnosed under controlled laboratory conditions. Full spatio-temporal imaging of blobs and associated energy and particle transport are obtained using conditional sampling of data from movable electrostatic probes with high spatial and temporal resolution. For the first time, the mechanism for plasma blob generation is experimentally identified on the basis of two-dimensional profiles of electron density and temperature, plasma potential and velocity fields. We show that blobs form from a radially elongated structure that is sheared off by the ExB flow. The structure originates from an interchange wave that increases in amplitude and extends radially in response to a decrease of the local radial pressure scale length. The dependence of the blob size upon the radial density gradient is also discussed. Two mechanisms for the transport across the magnetic field can be clearly quantified: the flux driven by the fluctuating density and potential associated with interchange modes, and the radially propagating blobs. Preliminary simulations of blob generation using a non-linear two-fluid numerical code are also presented.

4:00PM CI1.00005 A Compact Double-pass Raman Backscattering Amplifier/Compressor[1] ,
JUN REN, Princeton University — The resonant Stimulated Raman backscattering (SRBS) amplifier/compressor in plasma has been shown to move towards reaching ultra-high laser intensities [1,2]. However, the achieved energy transfer efficiency from pump to seed is still much below that predicted by theory [3]. We will present the enhancement of SRBS by introducing the proper plasma density gradient along the pump/seed interaction path. The energy transfer efficiency was significantly improved. The seed pulse was amplified by a factor of more than 10,000 from the input in a 2mm long plasma, which also exceeded the intensity of the pump pulse by almost 2 orders of magnitude. Moreover, this amplification was accompanied by very effective pulse compression, from 500 fsec down to 90 fsec, in a single pass. SRBS was further improved by a novel double-pass design, in which "left over" of the pump from the first pass and amplified seed were passed through the same plasma for another round of interaction. The energy transfer efficiency was increased by another factor of $\sim$ 2 and the pulse was compressed down to$\sim$50 fsec without increasing the size and cost of the system. The crucial result of the two-pass experiment was a very significant improvement in the efficiency of the system, with a 6.4% energy transfer from the pump to the ultra-short pulses. This result was more than a factor of 6 improvements in comparison to the best of our previous results [2], which makes this SRBS amplifier/compressor close to a practical device.
[1] Y. Ping, W. Cheng, and S. Suckewer, Phys.Rev.Lett. **92**, 175007 (2004).
[2] W. Cheng, Y. Avitzour, Y. Ping, S. Suckewer, N. J. Fisch, M. S. Hur, and J. S. Wurtele Phys. Rev. Lett. **94**, 045003 (2005).
[3] V. M. Malkin, G. Shvets, and N. J. Fisch, Phys. Rev. Lett. **82**, 4448 (1999).

[1]Presenter J. Ren, co-authors: W. Cheng, S. Li and S. Suckewer

4:30PM CI1.00006 Broadband Dielectric Function of Non-equilibrium Warm Dense Gold[1]

, YUAN PING, Lawrence Livermore National Laboratory — Warm Dense Matter refers to states in which the thermal and Fermi energies are comparable and the energy of Coulomb interaction between ions is greater than their kinetic energy. The behavior of such systems is dominated by electron degeneracy, excited electronic states and ion-ion correlations, rendering them a truly daunting many-body problem. Interest in Warm Dense Matter has been growing among broad disciplines including plasma physics, condensed matter physics, Inertial Confinement Fusion science, shock physics and material science under extreme conditions. This is driven by the fundamental urge to understand the convergence between plasma and condensed matter physics, and the practical need to understand dynamic behavior in the transformation of a cold solid into a high energy density plasma. A recent advance in this emerging field is the observation of the broadband optical properties of non-equilibrium warm dense gold at high energy densities. Using the approach of isochoric laser heating in a femtosecond pump-probe experiment we have obtained temporally resolved measurements of the dielectric function in the spectral range of 450-800nm [PRL 96, 255003 (2006)]. This allows us to unveil for the first time the behavior of intraband and interband transitions in warm dense gold at excitation energy densities of $10^6 - 10^7$ J/kg, providing an unique opportunity to examine effects of electron band structure and electron distribution. This talk is a review of the experimental technique and the new findings.
In collaboration with D. Hanson, I. Koslow, T. Ogitsu, D. Prendergast, E. Schwegler, G. Collins and A. Ng (UCRL-ABS-232890).

[1]Work performed under the auspices of the U.S. Department of Energy by the University of California LLNL under contract #W-7405-ENG-48 and also supported by NSERC, Canada

Monday, November 12, 2007 2:00PM - 3:00PM –
Session CT2 Tutorial: Laboratory Astrophysics Scaling Rosen Centre Hotel Salon 3/4

2:00PM CT2.00001 Scaling extreme astrophysical phenomena to the laboratory - a tutorial[1]

, BRUCE A. REMINGTON, Lawrence Livermore National Laboratory — The ability to experimentally study scaled aspects of the explosion dynamics of core-collapse supernovae (massive stars that explode from the inside out) or the radiation kinetics of accreting neutron stars or black holes on high energy density (HED) facilities, such as high power lasers and magnetic pinch facilities, is an exciting scientific development over the last two decades. [1,2] Additional areas of research that become accessible on modern HED facilities are studies of fundamental properties of matter in conditions relevant to planetary and stellar interiors, protostellar jet dynamics, and with the added tool of thermonuclear ignition on the National Ignition Facility, excited state ("multi-hit") nuclear physics, possibly relevant to nucleosynthesis. Techniques and methodologies for studying aspects of the physics of such extreme phenomena of the universe in millimeter scale parcels of plasma in the laboratory will be discussed.

[1] "Experimental astrophysics with high power lasers and Z pinches," B.A. Remington, R.P. Drake, D.D. Ryutov, Rev. Mod. Phys. 78, 755 (2006).
[2] "High energy density laboratory astrophysics," B.A. Remington, Plasma Phys. Cont. Fusion 47, A191 (2005).

[1]This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

Monday, November 12, 2007 2:00PM - 4:48PM –
Session CO3 NSTX and General Spherical Tokamak Rosen Centre Hotel Salon 9/10

2:00PM CO3.00001 Overview of the 2007 NSTX experimental campaign*

, D.A. GATES, PPPL, AND THE NSTX TEAM — The 2007 experimental campaign covered a wide range of scientific topics. Measurements of the turbulent electron fluctuation spectrum were made in many different plasma conditions including H-mode plasmas, L-mode plasmas, and plasmas with internal transport barriers using the microwave scattering system which spans a range in wavenumber to $k_\perp \rho_e \sim 1$. RWM feedback control has been explored with and without correction of time-varying error fields, allowing mode stabilization and plasma rotation sustainment throughout the discharge. The upgraded lithium evaporator was used extensively and was observed to raise the electron temperature in H-mode plasmas. Improved mode conversion of Electron Bernstein wave emission was observed in high elongation H-mode plasmas after lithium evaporation. A new Alfvén wave was observed, the β-induced Alfvén eigenmode, and β suppression of Alfvén cascades was also observed. Deuterium puffing has been used to produce partial divertor detachment in highly shaped plasmas without affecting plasma performance. A record electron temperature of 4.7keV was achieved using HHFW heating. Plasmas with high elongation $\kappa \sim 2.6$ have been maintained with high non-inductive current fraction $f_{NI} \sim 0.55$. These and other results will be summarized. *This work was supported by DoE contract No. DE-AC02-76CH03073

2:12PM CO3.00002 Experimental investigation of turbulent fluctuations with the scale of collisionless skin depth in NSTX plasmas[1]

, E. MAZZUCATO, R.E. BELL, J.C. HOSEA, B.P. LEBLANC, H.K. PARK, D.R. SMITH, J.R. WILSON, Princeton Plasma Physics Laboratory, C.W. DOMIER, N.C. LUHMANN, JR., U.C. Davis, W. LEE, Pohang University — Various numerical simulations support the conjecture that the ubiquitous problem of anomalous electron transport in tokamaks may arise from a turbulence driven by the electron temperature gradient, with large radial structures on the scale of the collisionless skin depth (δ_s). In this paper, we present results from measurements of turbulent fluctuations in the National Spherical Torus Experiment (NSTX), where the low level of ion transport anomaly makes plasma conditions uniquely suitable for the study of electron transport. Plasma density fluctuations are measured with coherent scattering of electromagnetic waves using a novel scattering geometry where the probing beam propagates obliquely to the magnetic field and the radial resolution of measured signals is greatly improved by the toroidal curvature of magnetic field lines. The onset of a broadband turbulence with a radial scale of $\sim \delta_s$ is observed during electron heating with high harmonic fast waves (HHFW). Numerical calculations are underway to identify the nature of observed fluctuations.

[1]Work supported by DOE Contract DE-AC02-76CH03073.

2:24PM CO3.00003 Internal transport barriers in NSTX reversed-shear plasmas[1]

, HOWARD YUH, F.M. LEVINTON, Nova Photonics, R.E. BELL, J.C. HOSEA, B.P. LEBLANC, D.R. SMITH, E. MAZZUCATO, H.K. PARK, S.M. KAYE, PPPL, S. KUBOTA, UCLA — Simultaneous internal transport barriers in both ion and electron channels have been observed in reversed shear ($dq/dr < 0$) discharges on NSTX. While these ITBs can be observed in discharges with only neutral beam heating, a HHFW (high-harmonic fast wave) RF power scan was performed at constant beam input power to scan the electron temperature gradient. Measurements show that the electron and ion transport barriers can be at different minor radii, suggesting different mechanisms for the suppression of ion and electron turbulence. Examination of the roles of magnetic and velocity shears with respect to ion and electron transport is possible through the use of CHERS and the newly upgraded 16 channel NSTX MSE diagnostic which now provides full coverage from the outboard plasma edge to past the magnetic axis with 3-4 cm resolution. Additional measurements from these well diagnosed plasmas, including Thomson scattering, X-ray diodes, reflectometry, and high-k fluctuations, will be examined in addition to results from TRANSP and GS2 linear simulations.

[1]This research was supported by U.S. DOE contracts DE-FG02-99ER54520 and DE-AC02-76CH03073

2:36PM CO3.00004 Beta Scaling and Momentum Transport Studies in NSTX , STANLEY KAYE, W. SOLOMON, R.E. BELL, B.P. LEBLANC, Princeton Plasma Physics Laboratory, F.M. LEVINTON, NOVA Photonics, J.E. MENARD, Princeton Plasma Physics Laboratory, S.A. SABBAGH, Columbia University, H. YUH, NOVA Photonics — Experiments have been carried out in NSTX to study both the beta scaling of confinement and momentum transport. Beta scaling studies were carried out at fixed collisionality and normalized electron gyroradius both in highly shaped plasmas (κ=2.1, δ=0.8) and in weakly-shaped plasmas (κ=1.8-1.9, δ=0.4). In the highly shaped plasmas, which exhibited small ELMS in the range of beta from 7 to 20%, no degradation of energy confinement was observed. In the more weakly shaped plasmas, the character and impact of ELMs changed markedly from low to high beta, leading to a severe degradation of confinement as beta increased. Momentum diffusivity in NSTX does not scale with ion thermal diffusivity, as at conventional aspect ratio, possibly due to suppression of ITG modes due to high ExB shear. Perturbative momentum transport studies, using non-resonant n=3 magnetic braking of the plasma, have been carried out, and these indicate momentum confinement times that are a factor of two to three greater than the energy confinement time, as well as significant inward momentum pinch velocities. This work is supported by United States DOE contract DE-AC02-76CH03073.

2:48PM CO3.00005 Gyroradius-Scale Ion Gradients in NSTX[1] , R.E. BELL, B.P. LEBLANC, PPPL, R. MAINGI, ORNL, S.A. SABBAGH, Columbia U. — The spherical torus geometry is well suited to compare experimental profiles on a fundamental transport scale. The low-field region in the low-aspect ratio NSTX along with a high spatial resolution charge exchange spectroscopy system make gyroradius-scale ion measurements possible. Ion temperature and density gradients with gyroradius-scale widths have been measured in some NSTX plasmas. Measured ion temperature changes of $\Delta T_i = 250 - 500$ eV are observed over $\Delta r \sim 1$ cm with total Larmor radius ~ 1 cm. Minimum gradient widths comparable to the larger banana orbit width would normally be expected from "random walk" arguments of neoclassical theory. Since radial electric field (E_r) gradients also vary on a gyro-radius scale, distortion of the gyro orbit is expected to cause orbit shrinking or orbit expansion [1], depending on the sign of E_r. Orbit shrinking removes the apparent discrepancy in the gradient width.

[1] K. C. Shaing, A. Y. Aydemir, R. D. Hazeltine, Phys. Plasmas 5, 3680 (1998).

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

3:00PM CO3.00006 Active Resistive Wall Mode Feedback with Expanded Sensors in NSTX[1] , S.A. SABBAGH, J.M. BIALEK, Columbia University, R.E. BELL, D.A. GATES, B.P. LEBLANC, J.E. MENARD, PPPL, NSTX TEAM — The resistive wall mode (RWM) active stabilization system on NSTX is expanded to include sensors measuring radial and poloidal mode components both above and below the plasma midplane. Various combinations of these control sensors are used to determine the effect on feedback performance. Plasma rotation and profile variation is generated by non-resonant magnetic braking using an applied n = 3 field configuration. Variation of the relative difference between the measured n = 1 RWM phase and the applied control field phase demonstrates both positive and negative feedback. Poloidal deformation of the mode observed during feedback at low plasma rotation [1] is examined with feedback using sensors both above and below the device midplane. Amplitude modulation of the measured n = 1 RWM sensor signal, thought to be resonant field amplification, can appear in both radial and poloidal sensors below the computed ideal MHD no-wall beta limit as determined by DCON stability analysis. The frequency of this modulation decreases as the RWM becomes unstable.

[1] S.A. Sabbagh, R. Bell, J.E. Menard, et al., *Phys. Rev. Lett.* **97**, 045004 (2006).

[1]Work supported by U.S. DOE Contracts DE-FG02-99ER54524 and DE-AC02-76CH03073.

3:12PM CO3.00007 Toroidal Alfven Eigenmode Avalanches on the National Spherical Torus Experiment[1] , ERIC FREDRICKSON, D. DARROW, N.N. GORELENKOV, S.S. MEDLEY, Princeton Plasma Physics Laboratory, Princeton, New Jersey, S. KUBOTA, N. CROCKER, UCLA, Los Angeles CA — Experiments on the National Spherical Torus Experiment have found the fast ion beta threshold for excitation of Toroidal Alfven Eigenmodes (TAE). A further increase in beam heating power is seen to push the TAE into a repetitive cycle of increasingly stronger bursts, each cycle culminating in a large, multi-mode burst and a drop in the neutron rate of approximately 10%. These strong bursts are identified as TAE avalanches [Nucl. Fusion 35 (1995) 1661]. In such an avalanche, the fast-ion phase-space islands describing the orbits of fast ions trapped in the TAE wave field have reached such an amplitude that islands from multiple modes overlap, leading to greatly enhanced transport of the fast ions, and a concomitant increase in the drive for the modes. Transport of fast ions in ITER is expected to be through a similar multi-mode interaction. Fast ion transport will be studied with NOVA and ORBIT, benchmarked on mode amplitudes measured with a multi-channel reflectometer array.

[1]Work supported by U.S. DOE Contract DE-AC02-76CH03073.

3:24PM CO3.00008 Dependence of the L-H power threshold on magnetic balance and heating method in NSTX[1] , R. MAINGI, T. BIEWER, Oak Ridge National Lab, H. MEYER, UKAEA Fusion-Culham, R. BELL, B. LEBLANC, Princeton Plasma Physics Lab, C.S. CHANG, New York University, NSTX TEAM — H-mode access is a critical issue for next step devices, such as the International Thermonuclear Experimental Reactor (ITER), which is projected to have a modest heating power margin over the projected L-H power threshold (PLH). The importance of a second X-point in setting the value of PLH has been clarified in recent experiments on several tokamaks. Specifically a reduction of PLH was observed when the magnetic configuration was changed from single null (SN) to double null (DN) in the MAST, NSTX, and ASDEX-Upgrade devices [1]. Motivated by these results, detailed PLH studies on NSTX have compared discharges with neutral beam and rf heating, as a function of drsep. Similar PLH values and edge parameters are observed with the two heating methods in the same magnetic configuration, with PLH $\sim$ 0.6 MW lowest in DN and increasing to $\sim$ 1.1 MW and 2-4 MW in lower-SN and upper-SN configurations respectively (ion grad-B-drift towards lower X-point). The evolution of the experimental profiles of parameters in L-mode before the L/H transition will be compared with simulations using the XGC code (C.S. Chang).

[1] MEYER, H. et al., Nucl. Fusion 46 (2006) 64.

[1]Sponsored by US DOE in part by contract #DE-AC05-00OR22725.

3:36PM CO3.00009 Overview of Transient CHI Plasma Start-up in NSTX and HIT-II , R. RAMAN, T.R. JARBOE, B.A. NELSON, University of Washington, D. MUELLER, M.G. BELL, Princeton Plasma Physics Laboratory — The capability for solenoid-free current generation provides greater flexibility in a tokamak reactor design by allowing access to lower aspect ratio configurations. NSTX is testing the method of transient coaxial helicity injection as a way of generating this current. This current is produced by discharging a capacitor across the lower divertor plates in the presence of toroidal and poloidal magnetic fields. This causes an expanding plasma to detach from the lower divertor plates resulting in the formation of a closed flux equilibrium. The method was originally developed in the HIT-II ST at the Univ. of Washington, where up to 100 kA of closed flux current was generated. Coupling this to induction resulted in CHI started discharges to consistently out-perform what was possible by induction alone, producing nearly 300 kA of current using only 52 mWb of solenoid flux. Recently application of this method on NSTX has resulted in the production of record levels of non-inductively generated closed flux current (>160 kA). Initial tests on NSTX have allowed coupling this current to induction from the central solenoid. *This work supported by U.S. DOE Contracts # DE-AC02-76CH03073and DE-FG02-99ER54519 AM08*

3:48PM CO3.00010 Non-Solenoidal Startup of the Ultra-Low Aspect Ratio Pegasus ST[1] , N.W. EIDIETIS, D.J. BATTAGLIA, M.W. BONGARD, M.J. FROST, G.D. GARSTKA, A.C. SONTAG, B.J. SQUIRES, E.A. UNTERBERG, University of Wisconsin-Madison — Pegasus is an extremely low aspect ratio tokamak exploring quasi-spherical, high-pressure plasmas and developing plasma formation and control techniques for future ST/tokamak applications. Non-inductive startup has been demonstrated using washer gun current sources in the lower divertor region. The injected current initially follows the helical structure of the crossed toroidal and vertical fields, but at extremely low field applied field ($B_V \approx .005$ T, $B_T \approx .01$ T) relaxation to a tokamak-like plasma occurs. Toroidal currents of 50 kA have been driven by less than 4 kA injected current. $I_N > 12$ MA/m-T is observed in these plasmas. Compatibility with ohmic operation has been demonstrated by successful hand-off of gun-produced plasmas to ohmic current drive. A mid-plane gun system, easily implemented on any machine with mid-plane port access, is presently under development. The formation of non-inductive plasmas and hand-off to ohmic induction has been demonstrated using this system. Current drive experiments using PF induction of a midplane seed plasma are underway.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

4:00PM CO3.00011 Recent EBW Emission Results on NSTX[1] , S.J. DIEM, G. TAYLOR, P.C. EFTHIMION, B.P. LEBLANC, Princeton U., J.B. CAUGHMAN, T.S. BIGELOW, J.B. WILGEN, ORNL, R.W. HARVEY, CompX, J. PREINHAELTER, J. URBAN, Czech Inst. of Plasma Phys., S.A. SABBAGH, Columbia U. — NSTX high beta plasmas operate in the overdense regime, allowing the electrostatic electron Bernstein wave (EBW) to propagate and be strongly absorbed and emitted at the electron cyclotron resonances. As such, EBWs may enable local electron temperature measurements and provide local electron heating and current drive. For these applications, efficient coupling between EBWs and electromagnetic waves outside the plasma is needed. Thermal EBW emission, measured on NSTX with two remotely steered, quad-ridged antennas, has been used to determine the EBW transmission efficiency for a wide range of plasma conditions. The antennas collect fundamental (8-18GHz), second and third (18-40 GHz) EBW emission via the oblique B-X-O mode conversion process. Recent H-mode results show that fundamental and second harmonic EBW transmission efficiencies >30% are observed for certain edge conditions. Experimental results from this diagnostic and comparisons to modeling will be presented.

[1]This work is supported by USDOE DE-AC02-76CH03073 and a grant to encourage innovations in fusion diagnostic systems.

4:12PM CO3.00012 Recent results from MAST spherical tokamak , ANTHONY FIELD, Culham Laboratory, MAST TEAM — Following installation of a new PINI source, the MAST spherical tokamak has been operating with up to 3.8 MW of NBI heating. The scaling of confinement could hence be determined over a greater range of power and current and integrated analysis of diagnostic data has facilitated transport analysis. First particle confinement data from pellet fueled plasmas has also been obtained. Density peaking in L-mode has been found to scale with normalised current density as in conventional tokamaks. Off-axis NBI current drive has been studied in extreme SND discharges. A new 28 GHz RF system has generated and sustained 33 kA of plasma current without the solenoid and EBW assisted start-up has also been demonstrated. Internal coils have been installed for ELM control and to excite TAE modes and study their damping. The structure and evolution of the edge radial E-field has been measured with a new edge spectroscopy system and first measurements of core density turbulence are available from a BES system. Further results on ELM structure, SOL filaments and the divertor plasma have also been obtained using improved edge diagnostics.

4:24PM CO3.00013 Investigation of transient phenomena on MAST using high resolution Thomson scattering , R. SCANNELL, M.J. WALSH, M. DUNSTAN, Culham Laboratory, MAST TEAM — The MAST tokamak is equipped with high spatial resolution Ruby laser and high time resolution Nd:YAG laser TS diagnostics. The Nd:YAG lasers are viewed by two separate sets of optics. One of these lens systems views the core region and measures at spatial resolution of 2.5-4cm and the other examines the plasma edge with 1cm resolution. This newly installed edge system has already produced a number of important results. In H-mode and L-mode filaments have been observed using laser time separations of 1-20μs. The high spatial resolution has allowed determination of the evolution of the outboard pressure pedestal, which plays a critical role in determining plasma stability. The variable time separation between lasers has also been exploited to study pellet deposition and retention in the plasma. A major upgrade to the core Nd:YAG system is now being planned. It is proposed to replace the current four lasers with a combined sampling rate of 200Hz at 1.0J with eight lasers with a combined sampling rate of 240Hz at 1.6J. The increase in laser energy together with new optics will allow the system to sample at high spatial resolution.

4:36PM CO3.00014 Lithium Loaded Target Plate for driving NSTX toward high performance[1] , LEONID E. ZAKHAROV, RICHARD MAJESKI, Princeton University, PPPL — Following CDX-U, the NSTX device in PPPL is on its way to the new plasma confinement and stability regimes when the pumping lithium surface will provide a high temperature plasma edge. Both ion and electron gradient turbulence is expected to be suppressed in this regime, while the finite edge current density at the separatrix will stabilize ELMs. So far, NSTX has made only a modest step in this direction using the LITER evaporators, which did improve the boundary conditions for the plasma but did not provide pumping of the plasma particles. Nevertheless, even with such modest implementation of the idea of the LiWalls a significant improvement of the confinement as well as ELM stabilization became evident on NSTX. The real step toward the high performance requires transition to a target divertor surface with molten lithium. The only option for NSTX, which was not designed for lithium pumping, is the Lithium Loaded Target Plate (LLTP), with inertial cooling by a copper substrate (separated from lithium by a thin stainless steel or other material foil). The talk describes the reference LiWall regime in NSTX with a 6 fold increase of the confinement time compared to its current value. It also describes the consistency of LLTP with heat and particle extraction from the plasma.

[1]Supported by US DoE contract No.DE–AC020–76–CHO–3073

Monday, November 12, 2007 2:00PM - 5:00PM –
Session CO5 Compression and Burn I Rosen Centre Hotel Salon 11/12

2:00PM CO5.00001 Measurable Lawson Criterium and Hydro-Equivalent Curves for Inertial Confinement Fusion , R. BETTI, C.D. ZHOU, Fusion Science Center and Laboratory for Laser Energetics, U. of Rochester — The Lawson's criterion that determines the onset of thermonuclear ignition is usually expressed through the product $p\tau \approx 10$ atm s, where p is the plasma pressure and τ is the energy confinement time. In magnetic fusion devices, both the pressure and confinement time are routinely measured, and the performance of each discharge can be assessed by comparing the value of $p\tau$ with respect to the ignition value (10 atm s). In inertial fusion, both p and τ cannot be directly measured and the performance of a subignited ICF implosion cannot be assessed with respect to the ignition condition. Here, we derive a form of the Lawson's criterion that can be directly measured in ICF implosions. Such a new ignition criterion depends on the only two measurable quantities in the ICF fuel assembly: the total areal density and the hot-spot ion temperature. In cryogenic implosions, the total areal density can be measured through secondary proton spectroscopy, neutron spectroscopy, or x-ray radiography. The ion temperature is measured with the neutron time-of-flight (nTOF) diagnostic. Thus, one can use such a new criterion to assess how far current and future subignited ICF implosions are from achieving ignition. This work was supported by the U.S. Department of Energy under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789.

2:12PM CO5.00002 Implosion experiments using $D_2\backslash^3He$ filled glass capsules doped with noble gases: A Study.[1] , JOHN BENAGE, GEORGE KYRALA, DOUG WILSON, MARK GUNDERSON, HANNA MAKARUK, Los Alamos National Lab, JOHANN FRENJE, C.K. LI, RICHARD PETRASSO, MIT, BARUCH YAAKOBI, LLE, WARREN GARBETT, AWE — When simulations are unable to match the yield in ICF implosion experiments, "mix" is commonly used to fix the simulation. If this fix is in any way assumed to model reality, then we are assuming that the simulations calculate the effect of the mix on the implosion and yield correctly. To study whether this assumption is valid, we have done a series of experiments that purposely add a fixed amount of mix of varying atomic number and density. The experiments are very well characterized, measuring the proton and neutron yields, the ion and electron temperatures, the ρR and radius of the capsule, the radiation emission, and the x-ray spectra from the capsule. We find that,in general, the calculations have great difficulty matching this data. A summary of the measurements for various dopants and dopant levels and how well the calculations compare will be presented. Some possible reasons for the modeling difficulties will be discussed along with some preliminary efforts to address these problems.

[1]Work supported by US DOE/NNSA under Contract DE-AC52-06NA25396.

2:24PM CO5.00003 Radiative Effects on Direct Drive Implosion Temperatures[1] , J.A. KOCH, H.-K. CHUNG, R. HEETER, W. HSING, R.W. LEE, A. MILES, H.-S. PARK, H. ROBEY, H. SCOTT, R. TOMMASINI, Lawrence Livermore National Laboratory, J. FRENJE, C.K. LI, R. PETRASSO, Plasma Science and Fusion Center, Massachusetts Institute of Technology, V. GLEBOV, University of Rochester, Laboratory for Laser Energetics — We have performed experiments at the Omega Laser Facility to measure time-resolved electron (Te) and ion temperature (Ti) in implosion plasmas. These experiments used direct laser drive on thin glass shells filled with a mixture of D, ^{3}He, Kr, and Xe, and used neutron and proton emission to diagnose Ti along with x-ray emission to diagnose Te. The Kr dopant serves as an optically-thin tracer for Te measurements via K-shell spectroscopy, while the Xe dopant enhances radiation losses and alters time-dependent temperatures through the shock and compression phases. These experiments are intended to establish an experimental platform for studying the energetics effects of high-Z dopants in hot, dense plasmas, including ignition plasmas at the National Ignition Facility. We describe the experiments and the supporting hydrodynamics simulations.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

2:36PM CO5.00004 Modeling NLTE effects in thin-shell direct-drive Omega capsule implosions[1] , A.R. MILES, J.A. KOCH, W. HSING, H.-S. PARK, H.F. ROBEY, H.A. SCOTT, Lawrence Livermore National Laboratory , J.A. FRENJE, C.K. LI, R.D. PETRASSO, F.H. SEGUIN, MIT, V.YU. GLEBOV, C. STOECKL, Laboratory for Laser Energetics, U. of Rochester — An experimental effort is currently underway in which thin (4 μm) glass-shell DHe3-filled capsules are fielded in direct-drive implosions at the OMEGA Laser Facility. The thin shells result in fast implosions and shock-heating of the gas to ion temperatures up to about 10 keV, while the electron and radiation temperatures remain significantly lower and separate from one another. One goal of these experiments is to obtain independent time-resolved measurements of these three temperatures in order to study matter-radiation coupling in a system that is nonequilibrium and can be made to be NLTE by adding high-Z dopants such as Xe. The addition of Xe has a strong imact on the implosion dynamics and TN yields, and makes the targets much more difficult to model via numerical simulations. In this paper, we compare simulation results obtained with different NLTE models and discuss requirements for reasonable agreement with the data.

[1]This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

2:48PM CO5.00005 Effects of ^{3}He Addition on Implosion of DT Capsules on Omega , H.W. HERRMANN, J.M. MACK, D.C. WILSON, J.R. LANGENBRUNNER, C.S. YOUNG, J.H. COOLEY, S.C. EVANS, T.J. SEDILLO, G.A. KYRALA, L. WELSER-SHERRILL, LANL, C.J. HORSFIELD, D.W. DREW, AWE, UK, E.K. MILLER, NSTec STL, V. YU GLEBOV, LLE, UR — Glass (SiGDP) capsules were imploded in direct drive on the Omega laser to look for anomalous degradation in yield (i.e., beyond what is predicted) with ^{3}He addition similar to the "factor of two" degradation previously reported by MIT at a 50% ^{3}He atom fraction (Rygg *et al,*. Phys. Plasmas 13, 2006). We did not see a significant anomalous degradation. The cause of the "Rygg" anomaly is as of yet unexplained, but differences in gas mixture (DT vs D_2) or shell parameters (glass vs plastic, diameter and wall thickness) may be responsible for the absence of this anomaly in the recent data. In addition, a short laser pulse (600 ps) was used to temporally separate shock and compression yield components in order to investigate mix. Previously, anomalously low compression yield had been observed when imploding glass targets containing 10 atm DT with 10 kJ of laser energy. This effect was not seen in the recent data with 5 atm DT and 15 kJ, and the resulting γ and n burn histories were in good qualitative agreement with predictions for ^{3}He addition. Work supported by US DOE/NNSA, performed by LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

3:00PM CO5.00006 Mix Degradation in DT Filled Capsules When Shock and Compression Yields are Resolved , D.C. WILSON, H.W. HERRMANN, J.M. MACK, C.S. YOUNG, G.A. KYRALA, J.H. COOLEY, L. WELSER-SHERRILL, J.R. LANGENBRUNNER, S.C. EVANS, T.J. SEDILLO, Los Alamos National Laboratory, C.J. HORSFIELD, D.W. DREW, AWE, Aldermaston UK, E.K. MILLER, NSTec STL, V. YU. GLEBOV, Laboratory for Laser Energetics, U. of Rochester — 1100μm dia. DT(5atm) + 3He (0,1,or 5 atm) filled glass capsules were directly driven on the Omega laser to measure yield, X-ray images, and especially the burn time history. The 600ps square pulse increases time separation between the "shock" yield (before the reflected shock reaches the incoming shell) and later "compression" yield. Matching the timing and amount of this early "shock" yield in the implosions fixes the electron conduction flux limiter. The Scannapieco and Cheng mix model results are compared with measured yield, burn temperatures and histories, and gated X-ray images. The experiment shows degradation of both the shock and compression yield, but relatively more degradation of the compression yield than explained by the model. The first gated images, which occur when the reflected shock reaches the incoming shell, show significant mixing has already occurred. But the lack of X-ray emission 60ps earlier suggests no mixing then. Work supported by US DOE/NNSA, performed by LANL, operated by LANS LLC under Contract DE-AC52-06NA25396. LA-UR-07-4929.

3:12PM CO5.00007 Evaluation and modeling of burn reaction histories using a directly driven capsule with two laser pulses , J.H. COOLEY, L. WELSER-SHERRILL, D.C. WILSON, H.W. HERRMANN, J.M. MACK, S.C. EVANS, T.J. SEDILLO, C.S. YOUNG, LANL, NM, C.J. HORSFIELD, D.W. DREW, AWE, UK, E.K. MILLER, NSTec STL, CA, V. YU. GLEBOV, C. STOEKL, LLE, UR, NY, R.A. LERCHE, LLNL, CA — Experiments were designed and fielded on the Omega laser to measure reaction history from capsules exposed to two distinct 600ps laser pulses. The purpose of the experiments was to produce a burn history with two peaks by using a time delay between the two laser pulses and thus obtain a compression and re-compression yield. However, although the results obtained produced two distinct yield peaks, further modeling indicated that the dynamics of the shell and in particular the mix of the ablator into the fuel were very different then our earlier understanding. These results and analysis will be presented and discussed. Work supported by US DOE/NNSA, performed by LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

3:24PM CO5.00008 Development of Shock-Timing Techniques for the National Ignition Facility , T.R. BOEHLY, M.A. BARRIOS, D.E. FRATANDUONO, T.C. SANGSTER, D.D. MEYERHOFER, Laboratory for Laser Energetics, U. of Rochester, P.M. CELLIERS, D. MUNRO, G.W. COLLINS, O.L. LANDEN, LLNL, R.E. OLSON, SNL — To optimize the drive for ignition targets on the National Ignition Facility, initial experiments will use surrogate targets to measure the timing and strength of shocks produced by that drive. These targets use an ignition-style capsule fitted with a deuterium-filled re-entrant cone embedded in that shell. The shocks are observed in flight through a transparent window using optical diagnostics. We report on OMEGA experiments that are scaled and designed to validate this shock-timing technique using both open geometry and hohlraum targets with embedded cones, by quantifying and mitigating the effects of preheat by hard-x-ray hohlraum emission on the inner capsule surface, deuterium column, and window. This work was supported by U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460.

3:36PM CO5.00009 X-Ray Ablation Rates of ICF Capsule Materials , R.E. OLSON, G.A. ROCHAU, R.J. LEEPER, SNL — Accurate knowledge of the X-ray ablation rates of low-Z capsule materials will be essential for successful indirect-drive ICF ignition experiments. We have performed experiments to measure the X-ray ablation rates in Be, Cu-doped Be, high density carbon (HDC), polystyrene (CH), Ge-doped CH, and polyimide. The X-ray fluxes were supplied by hohlraums driven by the Omega Laser at the University of Rochester [1]. The measurements were made in planar geometry utilizing diagnostic techniques described in Ref. 2. Be and Cu-doped Be have been selected as the ablator materials to be used in ignition capsules at U.S. National Ignition Facility (NIF). HDC has been selected as a NIF backup ablator. The ablation rates in Be and Cu-doped Be are in the range of 3-12 mg/cm^2/ns for hohlraum radiation temperatures of 160-250 eV. The HDC ablation rates are a bit lower, in the range of 2-9 mg/cm^2/ns for temperatures of 170-260 eV. The corresponding implied ablation pressures are in the range of 40-160 Mbar for beryllium and 20-140 Mbar for HDC. Our post-shot computational simulations are mostly within the uncertainties of the ablation rate measurements. An iterative rocket model has been developed and used to relate the planar ablation rate data to convergent Omega ablation rate experiments and also to full-scale NIF ignition capsule calculations. [1] T. R. Boehly et al., Opt. Commun. 133, 496 (1997). [2] R. E. Olson et al., Phys. Plasmas 11, 2778 (2004).

3:48PM CO5.00010 Time-resolved measurements of in-flight ablator performance using streaked x-ray radiography , DAMIEN HICKS, BRIAN SPEARS, CHUCK SORCE, PETER CELLIERS, OTTO LANDEN, GILBERT COLLINS, Lawrence Livermore National Laboratory, THOMAS BOEHLY, University of Rochester — Determining ablator performance during an implosion is a critical part of the NIF tuning campaign. In particular, it is vital to have an accurate, in-flight measure of the velocity, areal density, and mass of the ablator. We present a new technique which achieves time-resolved measurements of all these parameters in a single, area-backlit, streaked radiograph. This is accomplished by tomographically inverting the radiograph to determine the radial density profile at each time step; scalar quantities such as the average position, thickness, areal density, and mass of the ablator can then be determined simply by taking moments of this density profile. Application of this technique is demonstrated on Cu-doped Be capsule implosions at Omega. This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

4:00PM CO5.00011 Influence and measurement of mass ablation in ICF implosions[1] , BRIAN SPEARS, D. HICKS, C. VELSKO, M. STOYER, H. ROBEY, D. MUNRO, S. HAAN, O. LANDEN, Lawrence Livermore National Lab, D. WILSON, Los Alamos National Lab, A. NIKROO, General Atomics — Point design ignition capsules designed for the National Ignition Facility use an xray-driven Be(Cu) ablator to compress the DT fuel. Ignition specifications require the mass of unablated Be(Cu), called residual mass, be known to within 1% of the initial ablator mass when the fuel reaches peak velocity. We discuss the impact of variations in residual mass on the relevant capsule failure modes based on one- and two-dimensional radiation hydrodynamics. Experiments designed to measure and to tune the amount of residual mass are being developed as part of the National Ignition Campaign. We also discuss a set of measurement techniques that aim to measure the residual mass along with the peak velocity of the DT fuel. UCRL-ABS-232765

[1] This work was performed under the auspices of the Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

4:12PM CO5.00012 Monoenergetic Proton Radiography Studies of Matter and Field Distributions in Cone-in-Shell Capsule Implosions , J.R. RYGG, F.H. SEGUIN, C.K. LI, J.A. FRENJE, R.D. PETRASSO, MIT PSFC, R. BETTI, D.D. MEYERHOFER, C. STOEKL, W. THEOBALD, UR LLE — The matter and electromagnetic (E/B) field distributions in inertial confinement fusion implosions have been studied for the first time using monoenergetic proton radiography. Time-gated observations of the deflection and downshift of 14.7-MeV D^3He protons passing through implosions of cone-in-shell capsules were used to measure megagauss magnetic fields with complex topology in the capsule corona, areal densities in the capsule, and substantial blowoff of cone material. This work was supported by the Univ. of Rochester Fusion Science Center (Contract 412761-G).

4:24PM CO5.00013 Monoenergetic Proton Radiography Observations of E and B Field Evolution Outside Imploding, Direct-Drive ICF Capsules , F.H. SEGUIN, C.K. LI, J.R. RYGG, J.A. FRENJE, R.D. PETRASSO, MIT PSFC, R. BETTI, O.V. GOTCHEV, J.P. KNAUER, F.J. MARSHALL, D.D. MEYERHOFER, V.A. SMALYUK, UR LLE — Monoenergetic proton radiography has been used to make the first observations of electromagnetic fields that appear outside imploding inertial confinement fusion capsules as a result of laser-plasma interactions in direct-drive experiments at OMEGA. Images made with 15-MeV protons and $\sim$130 ps time resolution show that field structures that are roughly spherically symmetric form around the capsule shortly after the onset of laser illumination; these gradually change to radially filamented structures before dying away. Estimates of mode numbers and field strengths will be made, and the relationship between the field evolution and measured spectra of ablator ions will be discussed. This work was performed in part at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE, LLNL, LLE and FSC at Univ. Rochester.

4:36PM CO5.00014 Monoenergetic Proton Radiography Measurements of Implosion Dynamics in Direct-Drive Inertial Confinement Fusion , C.K. LI, F.H. SEGUIN, J.R. RYGG, J.A. FRENJE, R.D. PETRASSO, MIT PSFC, V.A. SMALYUK, R. BETTI, J. DELETTREZ, J.P. KNAUER, F.J. MARSHALL, D.D. MEYERHOFER, D. SHVARTS, UR LLE, R.P.J. TOWN, O.L. LANDEN, LLNL — Time-gated, monoenergetic proton radiography provides unique measurements of implosion dynamics of spherical capsules in direct-drive inertial confinement fusion. Proton radiographs obtained at different times, from acceleration through coasting, deceleration, and final stagnation, display a complete picture of ICF spherical implosion. Critical information inferred directly from such images uniquely characterizes the spatial structure and temporal evolution of plasma areal density and field distributions in an imploded target that was hitherto unavailable from conventional measurements. Data are contrasted with both self-emitted x rays and hydro simulations. The work described here was performed in part at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE, LLNL, LLE and FSC at the Univ. Rochester.

4:48PM CO5.00015 Double-shell capsules, an alternative to the single-shell cryogenic NIF design , G.R. MAGELSSEN, N.D. DELAMATER, M.A. GUNDERSON, I.L. TREGILLIS, M.J. SCHMITT, Los Alamos National Laboratory — Recently, Los Alamos has renewed its effort[1] to design and evaluate double-shell capsules as an alternative to the single- shell cryogenic NIF design.[2] The recent work by Livermore is being used as a starting point.[3-4] One to two megajoules of laser energy is used as input into the designs being considered. Sensitivity studies to P2 and P4 radiation flux asymmetries have been done and are presented in a separate talk.[5] Also, mix calculations of both the NIF capsule design and the double-shell design recently fielded on Omega3 will be presented in another talk.[6] Fully integrated calculations of the double-shell designs will be presented. Preliminary simulations with Rage, an Eulerian AMR code, will be shown that address the issue associated with gaps created by bringing two hemispheres together to create the outer shell. 1. M.S. Varnum et al., Phys. Rev. Lett. 84, 5153 (2000). 2. D.A. Callahan et al., Phys. of Plasmas 13, 56307 (2005). 3. P.A. Amendt et al., Phys. Rev. Lett. 94, 65004 (2005); private communication. 4. J.L. Milovich et al., Phys. of Plasmas 11, 1552 (2004). 5. I.L. Tregillis, this conference. 6. N.D. Delamater et al., this conference.
*Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

Monday, November 12, 2007 2:00PM - 5:00PM –
Session CO6 Short Pulse LPI I Rosen Centre Hotel Salon 5/6

2:00PM CO6.00001 Design of a Positron–Electron Pair-Plasma Production Experiment on OMEGA EP , J. MYATT, A.V. MAXIMOV, R.W. SHORT, D.D. MEYERHOFER, Laboratory for Laser Energetics, U. of Rochester — It is shown that an e^+e^- pair-plasma can be created on OMEGA EP, a feat yet to be achieved in the laboratory. Monte Carlo calculations show that a yield of between 10^{11} and 10^{12} positrons can be produced on OMEGA EP by a combination of the Bethe–Heitler conversion of hard-x-ray bremsstrahlung[1] and the trident process,[2] assuming a total laser energy of 5 kJ. For the expanding e^+e^- cloud to be a plasma, there must be many particles in a Debye sphere, and the cloud must be many Debye lengths in size. Particle-in-cell calculations are used to demonstrate that a megagauss DC magnetic field, produced by a second OMEGA EP beam, can be used to provide the necessary confinement and, therefore, density of the cloud. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics*, International Series in Pure and Applied Physics (McGraw-Hill, New York, 1964); D. A. Gryaznykh, Ya. Z. Kandiev, and V. A. Lykov, JETP Lett. **67**, 257 (1998); K. Nakashima and H. Takabe, Phys. Plasmas **9**, 1505 (2002).
[2] E. P. Liang *et al.*, Phys. Rev. Lett. **81**, 4887 (1998).

2:12PM CO6.00002 High-Brightness ∼keV Source and Diagnostic Development , C. STOECKL, W. THEOBALD, P.A. JAANIMAGI, P. NILSON, M. STORM, J.A. DELETTREZ, R. EPSTEIN, T.C. SANGSTER, Laboratory for Laser Energetics, U. of Rochester, D. HEY, A.J. MACKINNON, H.-S. PARK, P.K. PATEL, R. SHEPHERD, LLNL, J. GREEN, K.L. LANCASTER, P.A. NORREYS, RAL — High-energy-petawatt (HEPW), laser-driven backlighter sources with photon energies from ∼1 to ∼ 3 keV have a broad range of applications in high-energy-density physics and inertial confinement fusion. Backlighter source development studies have been performed on the VULCAN petawatt laser at RAL and the Multi-Terawatt laser at LLE and will be continued on OMEGA EP. The x-ray emission was measured on aluminum flat-foil targets. A conversion efficiency of up to 1×10^{-5} 1/eV/sr from laser energy into the Al He_α-line energy was observed. Assuming a circular emission region with a FWHM of ∼25 μm and an emission time of 30 ps a brilliance of ∼15 J/eV/ps/sr/cm^2 can be inferred. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

2:24PM CO6.00003 The Trident 250TW Short-Pulse Laser Upgrade at LANL: System and Initial Results[1] , J.C. FERNANDEZ, K.A. FLIPPO, C. GAUTIER, B.M. HEGELICH, R.P. JOHNSON, T. SHIMADA, J.B. WORKMAN, Los Alamos National Laboratory — The Trident laser-facility at Los Alamos has served for more than 20 years as an important tool in ICF and Material Dynamics research [1,2,3] An energy / power upgrade of the short pulse beam line to 150J / 250 TW and a new short pulse front end has been installed. Moreover, a third target area dedicated to combined short pulse / long pulse experiments is being built. The combination of this powerful new short-pulse beam line with the two flexible long pulse beams and a total of three different target areas, makes Trident a highly flexible and versatile research tool for high energy density laboratory plasma research. In this presentation, the upgraded capabilities are described, and results from initial operation are summarized.
[1] N. K. Moncur et al., Appl. Opt. **23**, 4274 (1995)
[2] D. S. Montgomery et al., PRL **87**, 155001 (2001)
[3] Swift, Damian C., et al., Phys Rev E **69**, 036406 (2004)

[1]This work is sponsored by the US DOE/NNSA and the LANL LDRD program.

2:36PM CO6.00004 Conversion efficiencies of 2D high energy Kα radiography embedded wire back lighters[1] , BRIAN MADDOX, HYE-SOOK PARK, BRUCE REMINGTON, MARK MCKERNAN, PRAVESH PATEL, SEBASTIEN LE PAPE, Lawrence Livermore National Laboratory — The absolute Kα yield of micro wire radiography back lighter targets was studied as a function of laser intensity and pointing to determine the effects of electron refluxing inside the substrates on Kα photon production. Silver wires measuring 10x10x300μm embedded into 100μm and 300μm square CH substrates were subject to short pulse, high intensity 1053nm laser light at the Titan laser facility. Laser pulse length was set to 40 ps with intensities from $3\mathrm{x}10^{17}$ to $3\mathrm{x}10^{18}$ W/cm^2. Conversion efficiencies into 22 keV Kα x-rays were measured using a CCD camera in single photon counting configuration, calibrated using Cd^{109} and Fe^{55} sealed sources. X-ray images of the laser focal spot at 65 eV and 256 eV were obtained to verify laser pointing and focus. Our results suggest refluxing plays only a minor role in Kα production; rather it is the direct coupling between the laser and the metal wire that dictates conversion efficiency. This work is in support of the Advanced Radiographic Capability (ARC) effort to use x-rays generated by high intensity, short pulse lasers as a diagnostic for experiments on NIF.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

2:48PM CO6.00005 Short-pulse laser K-alpha conversion efficiency in gas jet targets , N.L. KUGLAND, C.G. CONSTANTIN, P. NEUMAYER, A. COLLETTE, A.L. KRITCHER, E.L. DEWALD, J.S. ROSS, S.H. GLENZER, C. NIEMANN, PHYSICS DEPARTMENT, U.C. LOS ANGELES TEAM, LAWRENCE LIVERMORE NATIONAL LABORATORY TEAM, NUCLEAR ENG. DEPARTMENT, U.C. BERKELEY TEAM — We have measured the absolute conversion efficiency of K_α X-rays from short pulse laser irradiation of chlorine and argon gas jet targets, and performed a direct comparison of Cl K_α yield from both gaseous and solid chlorine-containing targets. The K_α conversion efficiencies in a 3.5% Cl gas jet target and a 100% Ar target ($n \approx 10^{19}$ cm^{-3}) are comparable to the conversion efficiency obtained for 33% Cl solid saran targets ($n \approx 10^{23}$ cm^{-3}). The conversion efficiency integrated from K_α to K_β is an order of magnitude higher in gas jet targets than in solid targets. This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory, through the Institute for Laser Science and Applications, under contract No. W-7405-Eng-48. This work was also supported by the Lawrence Livermore National Laboratory Student Employee Graduate Research Fellowship program.

3:00PM CO6.00006 High resolution 17 to 68 keV K-alpha backlighter for high-energy density experiments .[1] , HYE-SOOK PARK, B.R. MADDOX, M. KEY, S. LEPAPE, A.G. MACPHEE, P.K. PATEL, T.W. PHILLIPS, B.A. REMINGTON, R. TOMMASINI, Lawrence Livermore National Lab, C.A. BACK, E. GIRALDEZ, General Atomics — Backlighters of energy >17 keV are needed for many high energy density experiments on new facilities such as NIF and Omega-EP. Such high energy source can be created from hot electron interactions with target materials when illuminated by high intensity short pulse lasers. We carried out experiments to demonstrate that high energy 1-D and 2-D radiography is possible using micro-foils and small micro-wires (10 x 10 x 300 microns long) targets attached to low-Z substrates. We have tested Mo (17 keV), Ag (22 keV), Sm (40 keV) and Au (69 keV) micro-foil and micro-wire targets using the Titan laser at LLNL and utilized them to radiograph laser driven samples. We measure spatial resolutions better than 10 μm. We also measured K-alpha yields using a single hit CCD camera and a crystal spectrometer up to Pb (78 keV). This paper will present our radiography results and K-alpha source characteristics comparing them with the required signal level for NIF experiments.

[1]This work was performed under the auspices of U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

3:12PM CO6.00007 Polarized K-shell radiation due to anisotropic fast electron distribution in ultra-intense laser produced plasmas , TORU KAWAMURA, Tokyo Institute of Technology, TAKESHI KAI, ILE, Osaka University, FUMIHIRO KOIKE, Kitasato University, SHINOBU NAKAZAKI, University of Miyazaki, YUICHI INUBUSHI, YASUAKI OKANO, SHINSUKE FUJIOKA, TATSUFUMI NAKAMURA, TOMOYUKI JOHZAKI, HIDEO NAGATOMO, HIROAKI NISHIMURA, KUNIOKI MIMA, ILE, Osaka University — In fast ignition research, the transport of fast electrons generated by ultra-intense laser pulses is one of critical issues. To gain insight into the fast electron transport, polarized x-ray spectroscopy has been proposed. At a laser intensity of about $10^{17} W/cm^2$, the polarized K-shell radiation was observed [1]. A new time-dependent atomic population kinetics code has been developed [2], and the numerical predictions show that the polarization arises in corona region, and no polarization is found in dense region. An aspect ratio of anisotropic fast electron temperatures associated with longitudinal and transverse directions is correlated with the polarization. In the presentation, the prospect of fast electron transport will be discussed for fast ignition research. [1] H. Nishimura et al., PPCF, 47, B823 (2005). [2] T. Kai et al., PRA, 75, 012703 (2007), T.Kawamura et al., submitted (2007).

3:24PM CO6.00008 Laser Generated Ion Beams in the Context of Sandia's HEDP Mission[1] , MATTHIAS GEISSEL, BRIGGS ATHERTON, GUY BENNETT, AARON EDENS, PATRICK RAMBO, JENS SCHWARZ, Sandia National Laboratories, ERIK BRAMBRINK, LULI - Ecole Polytechnique — First experiments were performed at the 100 TW target area of the Z-Petawatt laser characterizing ion beam emission from laser irradiated solid density targets. These experiments addressed radiography and fast ignition concepts to be applied at the Z- Accelerator facility at Sandia National Laboratories. Cu, Al and Au targets were used for Target-Normal-Sheath- Acceleration of protons and heavier ions. Proton energies up to 30 MeV were measured, and the dependence of ion spectra on varying laser parameters was studied. An imaging proton spectrometer was used to investigate the acceleration due to field-enhancement effects at the target edge (edge emission). The usage of imaging plates was successfully introduced for charged particle beam analysis and compared to CR39 detector results.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SNL approval: SAND 2007-3217A.

3:36PM CO6.00009 2D Modeling of Field Ionization Role in Ion Acceleration from Thin Foils Irradiated by Laser Pulse of 10^{21} W/cm^2 Intensity , I.V. GLAZYRIN, RFNC-VNIITF, V.YU. BYCHENKOV, FIAN, A.V. KARPEEV, RFNC-VNIITF — Matter ionization under interaction of femtosecond Ti-Sa laser pulse of 10^{21} W/cm^2 intensity with Al foil of 0.1 μm thickness is determined with electric field. Electrons appeared after ionization are anisotropic in space, but developing Weibel instability makes electrons distribution function isotropic in time. Numerical simulations using 2D hybrid code (the PIC model for fast electrons and the MHD approach for thermal particles) have been done to study the role of field ionization of initially non-ionized Al. In the case of field ionization accountingamount of ions with the energy in the range of 20-100 MeV is more than by an order exceeds the amount of ions in the case of initial plasma set. This work was supported in part by the International Science and Technology Center (Project No. 2289).

3:48PM CO6.00010 Ion acceleration due to explosions of nanoparticles driven by hot electrons , MASAKATSU MURAKAMI, Institute of Laser Engineering, Osaka University, MOTOHIKO TANAKA, National Institute for Fusion Science — Plasma expansion into vacuum and resultant ion acceleration is studied both analytically and numerically, where the expansion of an initially uniform nanoparticle with radius R_{f0} and electron density n_{e0} is driven by explosion of thrmal electrons with initial temperature T_{e0}. Such key outputs as the energy spectrum, maximum ion kinetic energy, and electrons-to-ions energy transfer efficiency are explicitly given as a function of R_{f0}, n_{e0}, and T_{e0}. The simulation results turn out to be well reproduced by a self-similar solution [Phys. Plasmas Vol.13, 012105 (2006)], which describes an expansion of a finite-size non-quasi-neutral plasma mass into vacuum with a full account of charge separation effects.

4:00PM CO6.00011 Angular distribution of fast electrons and protons in short pulse laser target interaction[1] , HUI CHEN, Y. PING, S. WILKS, A. KEMP, R. SHEPHERD, LLNL, D. OFFERMANN, A. LINK, L. VAN WOERKOM, OSU, L. ELBERSON, U. Maryland, J. KING, UCSD, C. CHEN, MIT — Ultra intense short pulse laser pulses incident on solid targets can generate relativistic electrons either from direct laser electric field acceleration or the ponderomotive force associated with the gradient of the field. These electrons can then generate energetic protons due to the target normal sheath acceleration mechanism. These fast electrons and protons can effectively heat the solid target beyond the region of direct laser interaction and are important aspects of the fast ignition concept. One of the outstanding questions is the directionality of these fast particles, as the physics governing this will ultimately affect the energy transfer efficiency from laser to the compressed core. To this end, we have carried out experiments to systematically measure the angular distributions of fast electrons and protons for laser intensity from 10^{18} to 10^{20} Wcm^2 on the Callisto laser at LLNL for a variety of target materials and thickness, using multiple diagnostics. We found highly anisotropic distributions of particles for a variety of experimental conditions.

[1]This work was performed under the auspices of the U.S. DOE by UC LLNL under contract No. W-7405-Eng-48.

4:12PM CO6.00012 Influence of sheath fields on hot electron emission from small foils irradiated by intense laser pulses[1] , TOSHINORI YABUUCHI, HIDEAKI HABARA, TSUYOSHI TANIMOTO, KAZUO A. TANAKA, Graduate School of Engineering, Osaka Univ., TATSUFUMI NAKAMURA, KUNIOKI MIMA, Institute of Laser Engineering, Osaka Univ. — Strong sheath fields are excited around a rear surface of foils because hot electrons depart from foils irradiated by intense laser pulses. The field strength can be weakened because of a spreading of field-excited region caused by the charge flow on the foil surface. The field can inhibit the hot electron emission from the foils, therefore, the field strength has an influence on the emission number of hot electrons. The effect of field spreading on the electron emission is studied using foils with different areas. The signal intensity of hot electrons is reduced by 70% in our experiments when the inscribed radius of foils is reduced from 870 μm to 87 μm, which is much shorter than the laser pulse length ($\sim$ 200 μm). PIC simulations indicate that the number reduction is caused by a higher sheath potential in a small foil case. In that case, the sheath potential grows quickly and is high for a long period because the field spreading is restricted within the foil area.

[1]This work was supported by MEXT, Grant-in-Aid for Creative Scientific Research (15GS0214).

4:24PM CO6.00013 CPA backlighting using 1ω and 2ω light , STEVEN JAMES, COLIN BROWN, DAVID HOARTY, AWE Aldermaston — A number of materials modelling and radiation hydrodynamics experiments proposed for high power laser systems have requirements for high-energy (>20keV), high resolution ($\sim$10μm), short duration (>100ps) backlighters. One method of producing such a radiation source is the use of CPA lasers to produce fast-electron induced Kα fluorescence. The work outlined here covers the use of foils and fibres to produce radiographs of test resolution grids. Ag and Pd targets were illuminated with both 1ω and 2ω light from the HELEN CPA laser. Image plates were used to record an image of the test grid, which was used to determine source size and signal to background. An absolutely calibrated transmission crystal spectrograph was used to record the strength of the Kα line, and the conversion efficiency calculated. A hard X-ray spectrometer was used to measure the electron temperature. Conversion efficiencies of 10^{-4} were measured for 5μm thick foil targets, which produced <10μm resolution in one dimension. Slightly lower efficiencies were measured for 10μm fibre targets, $\sim$10μm resolution was measured parallel and perpendicular to the laser axis. No measurable effect of pre-pulse on the resolution was measured. The conversion efficiency with S-pol. 2ω laser light was significantly less than with P, as was the hot-electron fraction. P-pol. 2ω light produced lower K-alpha conversion efficiency than P-pol. 1ω, but with the advantage of reduced background.

4:36PM CO6.00014 Cone surface roughness and angle dependence in high intensity laser-plasma interactions , NATHALIE LE GALLOUDEC, University of Nevada, Reno, BYOUNG ICK CHO, University of Texas, Austin, EMMANUEL D'HUMIERES, University of Nevada, Reno, JENS OSTERHOLZ, University of Duesseldorf, Germany, YASUHIKO SENTOKU, University of Nevada, Reno, TODD DITMIRE, University of Texas, Austin — Cones targets of different surface roughness and angle were irradiated with the Thor laser (0.5J, 40fs, 800nm, 7micron focal spot, 3.10^{19}W/cm^2) at UT Austin. Smooth cones show surface structures of the order of 1-5 microns, while rough cones show surface structures of the order of 15 to 20 microns. A coordinated approach between the precision of laser parameters, available imaging diagnostics and target alignment, as well as optimizing signals on flat targets of similar material and thickness allowed us to systematically align and shoot these conical targets. Optical emission images, x-rays spectra, optical spectra of the emitted light from the tip were recorded. Preliminary data seem to suggest that a rough surface finish is more efficient. As an exploratory approach a few long nose targets were also shot. Experimental data and supporting simulations will be presented.

4:48PM CO6.00015 The Interaction of Low-Intensity Femtosecond Laser Pulses with a Copper Foil , N.G. KARLYKHANOV, V.A. LYKOV, RFNC-VNIITF — The results of experiments and theoretical research on interaction of femtosecond laser pulses at a wavelength 800 nm and 400 nm with a copper foil are presented. The Ti: Sapphire laser intensity on foil surface was in the rang of 10^{12}-$3{\cdot}10^{14}$ W/cm^2 in these experiments that were carried out at University of Alberta (Canada). The calculations of femtosecond laser pulses interaction with a matter and study of the foil blow-off are performed with using of the 1D ERA code developed in RFNC-VNIITF. This work was supported by ISTC on Project #2289.

2:00PM - 2:00PM –
Session CP8 Poster Session II: Reconnection and Non-Neutral I; Spheromaks and MCX; MFC Diagnostics; Simulation: Algorithm; Simulation: Kinetic/Edge Rosen Centre Hotel Grand Ballroom, 2:00pm - 5:00pm

CP8.00001 RECONNECTION AND NON-NEUTRAL I –

CP8.00002 Boundary conditions in magnetic reconnection[1] , J. EGEDAL, W. FOX, N. KATZ, A. LE, M. PORKOLAB, MIT, PSFC — Magnetic reconnection in the collisionless regime is studied on the Versatile Toroidal Facility (VTF) at MIT. The VTF device supports experiments with two distinct sets of boundary conditions: an "open" configuration for which the field lines intersect the vacuum vessel walls, and a "closed" configuration for which the magnetic field lines form closed loops inside the device. In the open configuration all electrons follow trapped trajectories. Our experimental and numerical studies reveal how these trapped electrons control the size of the reconnection region and mediate fast reconnection. This mechanism is found to be consistent observations by the WIND spacecraft in the deep magnetotail [1,2]. In the new closed configuration a parameter regime of special interest exists where the reconnection process appears in rapid bursts [3]. The vast differences in the experimental results for the two configurations emphasize the importance of boundary conditions. It suggests that there may not exist one unified theory for reconnection.

[1] M Oieroset, et al., (2002) Phys. Rev. Lett. 89, 195001.
[2] J Egedal, et al., (2005) Phys. Rev. Lett. 94, 025006.
[3] J Egedal, et al., (2007) Phys. Rev. Lett. 98, 015003.

[1]Work supported by a DOE Award DE-FG02-06ER54878 and a NSF/DOE Award PHY-0613734.

CP8.00003 Experimental study of fast fluctuations and turbulence during magnetic reconnection events on the VTF experiment[1] , W. FOX, M. PORKOLAB, J. EGEDAL, N. KATZ, A. LE, MIT PSFC — We present measurements of electrostatic fluctuations during reconnection events on the VTF experiment at MIT. Because we have found a regime in VTF where the reconnection is "bursty" in time [1], it is an ideal experiment for answering the long-standing question of whether current-driven turbulence plays an important role in the reconnection process. Our measurement system consists of high-bandwidth, impedance-matched Langmuir probes, digitized by a fast oscilloscope. Broadband fluctuations are observed, extending up to f_{ce} ($\simeq$ 1.5 GHz, $f_{pe}/f_{ce} \simeq 10$), coincident with reconnection events both in time and space. Arrays of probes and standard cross-correlation analysis provide wavelength measurements. Non-linear phenomena, such as discrete positive potential spikes, traveling at $\sim$2-3 v_{te} and with spatial width 1-2 mm ($\simeq 50-100\ \lambda_{De}$) are also observed coincident with large reconnection events. Finally, we will discuss various instability mechanisms, with insight from a recently-installed electron energy analyzer.

[1] J. Egedal, *et al.* (2007). PRL **98**, 015003.

[1]Support from CMPD (DOE contract DE-FC02-04ER54786), DOE (DE-FG02-06ER54878), and NSF/DOE (PHY-0613734)

CP8.00004 Three-Dimensional Magnetic and Electrostatic Measurements of Spontaneous Magnetic Reconnection[1] , A. LE, J. EGEDAL, W. FOX, N. KATZ, M. PORKOLAB, MIT, PSFC — A new closed magnetic configuration has recently been implemented in the Versatile Toroidal Facility (VTF) utilizing internal coils to generate a poloidal field with a characteristic X-line geometry. Although driven uniformly, reconnection often occurs in short, rapid bursts triggered internally in the plasma [1]. To study in detail the onset of fast magnetic reconnection and the accompanying three- dimensional plasma dynamics, new arrays of magnetic and electrostatic probes have been constructed. These yield high- resolution profiles of the magnetic field simultaneously at several toroidal locations. Here we present preliminary measurements on the dynamical onset and evolution of fast reconnection.

[1] J Egedal, et al., (2007) Phys. Rev. Lett. 98, 015003.

[1]Work supported by a DOE Junior Faculty Award DE-FG02-06ER54878 and a NSF/DOE Award PHY-0613734

CP8.00005 Experiments on the Propagation of Plasma Blobs[1] , NOAM KATZ, JAN EGEDAL, WILL FOX, MIKLOS PORKOLAB, MIT — We investigate the large-scale motion of plasma blobs in the Versatile Toroidal Facility (VTF) using Langmuir probe arrays. Blobs, or field-aligned filaments, have been used to model plasma fluctuations in the scrape-off layer of tokamaks and other devices [1-3]. These fluctuations, which are interchange modes driven by magnetic field curvature, display a convective or 'bursty' character and can sometimes form large coherent structures. We use VTF, a well-diagnosed basic plasma physics experiment, to create plasma blobs reproducibly. The experiments are designed to investigate how the average blob speed scales with various experimental parameters and to probe the internal electrostatic structure of the blobs. We find that charge exchange collisions with neutrals play a significant role in the non-linear evolution of the plasma structures. [1] Krasheninnikov S, Phys. Lett. A, 283 (2001) 368 [2] Zweben S et al, Nucl. Fusion, 44 (2004) 134 [3] Garcia O et al, Phys. Plasmas, 12 (2005) 090701

[1]This work partly funded by DOE Junior Faculty Award DE-FG02-06ER54878 and NSF/DOE Award PHY-0613734. N. Katz partly funded by a Fusion Energy Sciences Fellowship, administered by ORISE. W. Fox and N. Katz partly funded by CMPD Award DE-FC02-04ER54786

CP8.00006 On the filamentary structure of energetic electrons during reconnection in flares , J.F. DRAKE, UC Berkeley, R. FERMO, M. SWISDAK, UMD, M.A. SHAY, U Delaware — Simulations are presented that demonstrate that magnetic reconnection in the corona does not occur as a single large-scale x-line. Rather the narrow current layers that form at x-lines form secondary magnetic islands that grow and merge to produce a turbulent bath of islands. A probability model of island growth is being developed to predict their size spectrum. A consequence of particle acceleration in any multi-island system is that energetic particles are released in narrow streams with characteristic widths controlled by the width of the dissipation region (electron skin depth) as the islands reconnect with the external macro-scale field. Thus, energetic electrons do not propagate away from the reconnection site to the solar surface as a single large-scale front but as a filamentary web. We show that the filaments of energetic particles propagate along the magnetic field as kinetic Alfven waves with propagation speeds comparable to the thermal velocity of the energetic particles. The return current therefore does not inhibit the transport of energetic particles. The kinetic Alfven wave should similarly facilitate the transport of energetic electrons to the ionosphere during substorms in the magnetosphere.

CP8.00007 The Onset of Fast Magnetic Reconnection is Localized , JOHN MEYER, PAUL CASSAK, MICHAEL SHAY, University of Delaware, JAMES DRAKE, University of Maryland, BRUNO ECKHARDT, Phillips-Universitat Marburg — A subject of ongoing debate in the literature concerns the dependence of (fast) Hall reconnection on the system size, which is related to the issue of reconnection onset. Does the trigger occur near the boundary and propagate inward or is reconnection initiated near the X-line and propagate outward? Numerical simulations supporting either scenario exist. We present new evidence that the trigger is localized near the X-line, suggesting that local physics rather than global dynamics controls Hall reconnection. This is done by demonstrating the existence of an unstable steady-state magnetic reconnection solution which lies at the boundary of the basins of attraction of the Sweet-Parker and Hall reconnection solutions. Its identification required a novel iterative numerical technique. Eigenmodes of the unstable solution are localized near the X-line, suggesting that the onset of fast reconnection in a weakly collisional plasma initiates at the X-line. We will discuss these results in the context of other theories of fast magnetic reconnection.

CP8.00008 Two-scale structure of the electron dissipation region during collisionless magnetic reconnection: PIC simulations and Cluster satellite observations , MICHAEL SHAY, JAMES DRAKE, MARC SWISDAK, TAI PHAN, JONATHAN EASTWOOD, University of Delaware — Particle in cell (PIC) simulations[1] and Cluster satellite observations of collisionless magnetic reconnection are presented that demonstrate that the electron dissipation region develops a distinct two-scale structure along the outflow direction. Consistent with past hybrid and two-fluid simulations, the rate of reconnection remains fast in very large systems, independent of the mass of the electrons. A surprise is the existence of an outer electron dissipation region downstream of the inner one, which extends up to 40 ion inertial lengths downstream of the X-line in the largest simulations. This outer region consists of a super-Alfvenic jet of electrons which are decoupled from the magnetic field. The existence of this outer dissipation region is confirmed by Cluster satellite observations during a current sheet crossing in the flanks of the dayside magnetopause about 30 ion inertial lengths downstream of an x-line.

[1] Shay, M. A., J. F. Drake, and M. Swisdak, "Two-scale structure of the electron dissipation region during collisionless magnetic reconnection," Submitted to Physical Review Letters, arXiv:0704.0818v1 [physics.plasm-ph]

CP8.00009 Asymmetric Magnetic Reconnection: General Theory and Collisional Simulations , PAUL CASSAK, MICHAEL SHAY, University of Delaware — Theories of magnetic reconnection usually assume that the plasmas on either side of the dissipation region have identical densities and magnetic field strengths. However, this canonical description is rarely realized in nature. There has been wide interest in the shock structure of fast reconnection, particularly at the dayside magnetopause, but a general theory of the structure of the dissipation region and the rate of reconnection during asymmetric reconnection has not been addressed. We derive analytical expressions from first principles using a Sweet-Parker type scaling analysis. Most of the scaling results are independent of the dissipation mechanism and, therefore, apply to asymmetric reconnection in general. Furthermore, we show that a generic feature of asymmetric reconnection is that the X-line and stagnation point are not colocated. This implies that there is a bulk flow of plasma across the X-line, as has been seen in many numerical studies and observations at the dayside. The theory is verified using two dimensional collisional magnetohydrodynamic simulations. Applications to the magnetosphere are discussed.

CP8.00010 Diamagnetic effects in driven magnetic reconnection[1] , JULIO MARTINELL, ICN, UNAM, Mexico, JESUS RAMOS, PSFC, MIT — We use the two-fluid equations recently derived in [1] to study magnetic reconnection about a neutral X-point in a weakly collisional plasma, driven by external bulk flow. The equations include finite Larmor radius effects and are valid for arbitray density and temperature gradients thus accounting for complete diamagnetic effects. They also allow for strong temperature anisotropies and arbitrarily large fluctuation amplitudes, which make them appropriate for nonlinear studies. The resulting reduced model, in which the fast magnetosonic wave is suppresed, consists of seven fields: density n, four pressures $p_{\alpha\|}$, $p_{\alpha\perp}$, magnetic potential ψ and electric potential Φ. The evolution of the system is followed using a numerical code producing a forcing from the edge of the integration domain that starts from zero during a finite time (Taylor problem). We proceed by adding different effects gradually in order to asses the role of each one and comparing with a standard reduced model [2] without the electron inertia. The first and simplest case is for an isotropic plasma with constant temperature. Then we include finite temperature gradients and finally the effect of anisotropic pressures for both ions and electrons. [1] J.J. Ramos, Phys. Plasmas **14**, 052506 (2007) [2] T.J. Schep, et al., Phys. Plasmas **1**, 2843 (1994)

[1]Supported by grants CONACyT-44324 and DGAPA IN115205

CP8.00011 A first-principles analytical theory for 2D magnetic reconnection in electron and Hall MHD. , A. ZOCCO, A.N. SIMAKOV, L. CHACON, LANL — While the relevance of two-fluid effects in fast magnetic reconnection is well-known,[1] a first-principles theory –akin to Sweet and Parker's in resistive MHD– has been elusive. Here, we present such a first principles steady-state theory for electron MHD,[2] and its extension to Hall.[3] The theory discretizes the extended MHD equations at the reconnection site, leading to a set of time-dependent ODEs. Their steady-state analysis provides predictions for the scaling of relevant quantities with the dissipation coefficients (e.g, resistivity and hyper-resistivity) and other relevant parameters. In particular, we will show that EMHD admits both elongated and open-X point configurations of the reconnection region, and that the reconnection rate E_z can be shown not to scale explicitly with the dissipation parameters. This analytic result confirms earlier computational work on the possibility of fast (dissipation-independent) magnetic reconnection in EMHD. We have extended the EMHD results to Hall MHD, and have found a general scaling law for the reconnection rate (and associated length scales) that bridges the gap between resistive and EMHD.

[1]J. Birn et al., *J. Geophys. Res.*, **106** (A3), pp. 3715–3719 (2001)
[2]L. Chacón, A. N. Simakov, A. Zocco, *Phys. Rev. Lett.*, submitted
[3]A. N. Simakov, L. Chacón, in preparation

CP8.00012 Energetic electrons and magnetic islands during reconnection[1] , L.-J. CHEN, N. BESSHO, University of New Hampshire, W. DAUGHTON, LANL, A. BHATTACHARJEE, UNH — Magnetic reconnection is widely thought to be a mechanism for electron acceleration, but exactly where and how the acceleration occurs remains an open question. Here we report case studies of magnetotail reconnection where energetic electrons and signatures of magnetic islands are observed. We found that each clearly identifiable magnetic island has a corresponding burst of energetic electrons, but strong energetic electron bursts can appear without the association with well-defined single islands. Energetic electrons are also observed at the electron current sheet, but with a much lower energy and flux that is one order of magnitude lower than those within islands. The fluxes of energetic electrons peak at sites of compressed density within magnetic islands, a feature not explained by existing theories. Strong core magnetic fields are observed within islands even for cases when the background guide field is less than 1% of the asymptotic field. The existence of strong core fields indicate that energetic electrons are either being actively produced within or introduced into the islands. because otherwise the electrons will be guided away within $\ll 1$ second. The strong density sub-structures within islands suggest that the islands may have gone through coalescence. The observation will be compared with PIC simulations of reconnection to better understand acceleration mechanisms.

[1]We acknowledge the entire Cluster team for contributing to the data used in this study.

CP8.00013 PIC simulations of core magnetic field generation in magnetic islands by reconnection , N. BESSHO, L.-J. CHEN, A. BHATTACHARJEE, Center for Integrated Computation and Analysis of Reconnection and Turbulence (CICART), University of New Hampshire — We will present results of particle-in-cell (PIC) simulations where core field generation in magnetic islands by magnetic reconnection is studied. Cluster observations reveal that multiple magnetic islands are generated by reconnection in Earth's magnetotail, and some islands have strong core fields accompanied by peaks of electron density and energetic electron flux. Using a 2D PIC simulation code, we study magnetic reconnection with multiple X-lines and magnetic islands. We will show that each X-line has a quadrupolar magnetic field due to magnetic reconnection, and at the same time, strong core fields are generated in magnetic islands even when the initial guide field is very small ($< 0.01B_0$, where B_0 is the asymptotic magnetic field). Some simulation results show that the peak of the core field is located at the center of each island in an early stage of the evolution of islands. As the islands evolve, the structure changes and each island has multiple peaks of core fields in a later stage. We will also study energy spectra of electrons in those islands. This research is supported by NSF, NASA, and DOE.

CP8.00014 Collisionless Magnetic Reconnection in Large-Scale Electron-Positron Plasmas , W. DAUGHTON, H. KARIMABADI, L. YIN, B.J. ALBRIGHT, K. BOWERS, Los Alamos National Laboratory — One of the most fundamental questions in reconnection physics is how the dynamical evolution will scale to macroscopic systems of physical relevance. This issue was recently examined for electron-positron plasmas using 2D kinetic simulations with both open and periodic boundary conditions[1]. The initial phase is distinguished by the coalescence of tearing islands to larger scale while the later phase is marked by the expansion of diffusion regions into elongated current layers that are intrinsically unstable to plasmoid generation. It appears that the repeated formation and ejection of plasmoids plays a key role in controlling the average structure of a diffusion region and preventing the further elongation of the layer. Although the specific details of this evolution are affected by the boundary and initial conditions, the time averaged reconnection rate remains fast and is remarkably insensitive to the system size for sufficiently large systems. In this work, the influence of a guide field and current aligned instabilities are examined in 3D simulations. The mechanism of repeated plasmoid formation identified in 2D is also observed in these large-scale 3D simulations. This dynamic scenario offers an alternative explanation for fast reconnection in large-scale systems.

[1]Daughton and Karimabadi, *Phys. Plasmas* **14**, 072303, 2007

CP8.00015 Kinetic Theory and Simulation of Collisionless Tearing in Bifurcated Current Sheets , TATSUKI MATSUI, University of Iowa, WILLIAM DAUGHTON, Los Alamos National Laboratory, VADIM ROYTERSHTEYN, University of Iowa — Bifurcated current sheets have been observed in the Earth's magnetotail and also within kinetic simulations. The development of a bifurcated current layer may be the direct result of magnetic reconnection or may be due to the nonlinear evolution of the lower-hybrid drift instability. Although the equilibrium theory of these structures has been considered by a number of researchers, the linear stability has not been rigorously treated. In this work, a Vlasov equilibrium is constructed that permits both the current bifurcation and temperature anisotropy to be independently adjusted. The linear theory for colllisionless tearing is performed using standard techniques and compared against a formally exact numerical treatment. The resulting dispersion relation and mode structure are verified with fully kinetic particle-in-cell simulations. While temperature anisotropy $T_\perp > T_\|$ is always strongly destabilizing, the bifurcated current profile enters as a stabilizing influence on the tearing mode. A simplified analytic theory is reasonably accurate for long wavelength modes, but the short wavelength regime requires the full numerical treatment to accurately compute the growth rate.

CP8.00016 The Influence of Sheared Parallel Flows on Collisionless Magnetic Reconnection

, V. ROYTERSHTEYN, The University of Iowa, W. DAUGHTON, Los Alamos National Laboratory — The first results of an ongoing study of the influence of sheared parallel flows on collisionless magnetic reconnection are presented. In particular, we focus on the linear stability of a newly developed exact kinetic equilibrium which incorporates sheared parallel flows into the well-known Harris current sheet configuration. Using a variety of tools including analytical theory, numerical solution of the complete linearized Vlasov-Maxwell system, and fully kinetic 2D PIC simulations, we demonstrate that the stability properties of a thin current sheet in the presence of significant (of the order of ion thermal speed) flows differ significantly from those predicted by MHD analysis. Large flow shear is typically found to have a stabilizing influence on the reconnecting mode, while the shear-driven instability, which has been proposed as the mechanism responsible for the onset of reconnection, is either completely stable, or has growth rate that is dramatically lower than that predicted by MHD analysis. Preliminary results from nonlinear PIC simulations indicate that the onset of fast reconnection proceeds in a manner that is similar to that in the absence of the flow. None of the simulations exhibit highly wrapped vortices typically produced by MHD simulations of similar configurations.

CP8.00017 Forced Magnetic Reconnection with Open Boundary Conditions

, WEIGANG WAN, GIOVANNI LAPENTA[1], Los Alamos National Laboratory — We present kinetic simulations of collisionless forced magnetic reconnection driven by different models of magnetic flux inflows, with open boundary conditions applied in the outflow directions. We use the implicit Particle-in-Cell code CELESTE3D [1], which retains kinetic effects for both electrons and ions. Different from results of fluid simulations, the reconnection rate is intermittent rather than steady even when the driving inflow is constant. Similar to the pervious discoveries by W. Daughton *et al.* [2], we find secondary islands grow as the electron diffusion region is elongated over time. For the well-studied Newton Challenge reconnection problem, compared to results with periodic boundary conditions, here we find that with the open boundaries, at the same driving amplitude, fast reconnection starts earlier and reaches a bigger maximum reconnection rate. We will study the dependence of the maximum reconnection rate on the driving amplitude and other factors. References: [1] G. Lapenta, J. U. Brackbill, and P. Ricci, Phys. Plasmas **13**, 055904 (2006) [2] W. Daughton, J. Scudder and H. Karimabadi, Phys. Plasmas **13**, 072101 (2006)

[1]also at Centrum voor Plasma-Astrofysica,Departement Wiskunde, Katholieke Universiteit Leuven,Celestijnenlaan 200B, 3001 Leuven, Belgium

CP8.00018 Micro-macro coupling in 3D reconnection

, GIOVANNI LAPENTA, LANL & KU-Leuven, WEIGANG WAN, LANL — 3D reconnection is a process that differs in many ways from the much-studied 2D reconnection. We focus here primarily on two issues that are distinctly 3D: topology and micro-macro coupling. Topology in 3D reconnection can take much more complex forms from the conventional 2D x-point configuration, including the 2D-like reconnection in presence of x-lines but also uniquely 3D concepts such as null point reconnection. We will demonstrate instances of both types of configurations in 3D kinetic simulations. Micro-marco coupling in 3D reconnection is much richer than in 2D because of the presence of many more modes and instabilities propagating in directions outside the reconnection plane. The nature of the instabilities present depends crucially on the type of equilibria considered and especially by the presence of so-called guide fields. We consider here the spectrum of small scale modes present in a initially Harris equilibrium with different guide fields. We focus on identifying the nature of the microinstabilities and their interaction with large scale topological changes.

CP8.00019 Micro-reconnection at the c/ω_{pe} Scale Length*

, K. TUMMEL, B. COPPI, MIT — A phase space (non-fluid) approach is needed to describe modes that perturb the magnetic field in a sheared field geometry, lead to the formation of strings of magnetic islands, and have transverse scale distances that are of the order of c/ω_{pe}. The driving factor is the transverse electron temperature gradient. The plasma density gradient has a strong influence and is shown to reduce the mode frequency considerably relative to its upper bound $k_\perp c|dT_e/dr|/(eB)$. The mode characteristics are intrinsically different from the commonly known electrostatic ETG modes, that do not produce magnetic islands and have shorter wavelengths. The effect of the present modes is to decrease the anisotropy of the electron thermal conductivities by increasing the ratio of $D^{th}_{\perp e}/D^{th}_{\parallel e}$ relative to its very small classical value. In particular $D^{th}_{\perp e}$ is estimated as $\alpha_D(c/\omega_{pe})c|dT_e/dr|/(eB)$ where α_D is a finite numerical coefficient. The theory of mesoscopic reconnecting modes (so-called drift-tearing) that can produce macroscopic magnetic islands depends heavily[1] on the finiteness of $D^{th}_{\perp e}/D^{th}_{\parallel e}$ besides that of electrical resistivity. Therefore it has been assumed that these mesoscopic modes develop[1] from a background of micro-reconnecting modes of the kind we have described. *Sponsored in part by the US D.O.E.

[1]B. Coppi in "Collective Processes in Macroscopic Systems" Eds. G. Bertin *et al.*, Publ. *World Scientific* (2007) and MIT-LNS Report 06/11 (2006).

CP8.00020 Roles of Magnetic Reconnection and Developments of Modern Theory*

, B. COPPI, MIT — The role of reconnection was recognized in Solar and Space Physics and auroral substorms were suggested to originate in the night-side of the Earth's magnetosphere as a result collisionless reconnection[1] well before the kind of modern theory employed for this became applied to laboratory plasmas. Experiments have reached low collisionality regimes where, like in space plasmas, the features of the electron distribution and in particular of the electron temperature gradient become important and the factors contributing to the electron thermal energy balance equation (transverse thermal and longitudinal diffusivities, or electron Landau damping[2] play a key role. For this an asymptotic theory of modes producing macroscopic islands has been developed involving 3 regions, the innermost one related to finite resistivity and the intermediate one to the finite ratio of the to thermal conductivities[3],[4]. A background of excited micro-reconnecting modes, driven by the electron temperature gradient, is considered to make this ratio significant[4] *Supported in part by the US D.O.E.

[1]B. Coppi, *Nature* **205**, 998 (1965).

[2]B. Coppi, J.W.-K. Mark, L. Sugiyama, G. Bertin, *Phys. Rev. Letters* **42**, 1058 (1978) and J. Drake, *et al.*, *Phys. Fluids* **26**, 2509 (1983).

[3]B. Coppi, C. Crabtree, and V. Roytershteyn contribution to Paper TH/R2−19, I.A.E.A. Conference 2006.

[4]B. Coppi, in *"Collective Phenomena in Macroscopic Systems"* Eds. G. Bertin *et al.* (World Scientific, 2007) MIT-LNS Report 06/11(2006).

CP8.00021 Overview of recent results from the Columbia Non-neutral Torus and future plans[1]

, THOMAS SUNN PEDERSEN, Columbia University, J.W. BERKERY, A.H. BOOZER, Q.R. MARKSTEINER, M.S. HAHN, P.W. BRENNER, B. DURAND DE GEVIGNEY, J.P. KREMER, R.G. LEFRANCOIS, H. HIMURA, Kyoto Inst. of Tech., Kyoto, Japan — The Columbia Non-neutral Torus (CNT) is a compact, two-period stellarator created from four circular coils, dedicated to the study of non-neutral and electron-positron plasmas on magnetic surfaces. First results include the confirmation that pure electron plasmas can be confined stably in a stellarator, with confinement times of up to 20 msec. Transport is driven by the perturbing presence of internal rods, as well as by electron-neutral collisions. CNT has started operating with a retractable emitter allowing operation without internal rods, eliminating this source of transport. Reducing the neutral driven transport by reducing the neutral pressure to less than 2×10^{-10} Torr, a confinement time exceeding 1 second is predicted. Despite the long confinement times, the collisional transport rate is much higher than expected from neoclassical predictions. In fact, confinement times are on the order of the electron-neutral collision time, possibly caused by bad orbits despite the large radial electric field. This poster will give an overview of recent CNT results and future plans.

[1]Supported by NSF-DOE, NSF-PHY-04-49813 and NSF-PHY-06-13662

CP8.00022 Confinement of pure electron plasmas in the Columbia Non-neutral Torus , JOHN BERKERY, THOMAS PEDERSEN, ALLEN BOOZER, PAUL BRENNER, QUINN MARKSTEINER, MICHAEL HAHN, JASON KREMER, Columbia University — One goal of the Columbia Non-neutral Torus (CNT) research program is to investigate the possibility of enhanced confinement in stellarators due to high electric fields. Non-neutral plasmas with high electric fields are predicted to have long confinement times. Measured confinement times have fallen somewhat short of these predictions, however. There are several factors influencing the transport in these plasmas, including the presence of insulated rods, the neutral pressure, the ion fraction (through ion-driven instabilities), the match of equipotential and magnetic surfaces, and possibly prompt losses due to bad orbits. Each of these factors has been or is presently being investigated in CNT. Results are presented from the theoretical scaling of the neoclassical confinement time, and the measured confinement time's dependence on the presence of rods and on the neutral pressure. Comparisons are made between the predicted and measured values and possible explanations for the discrepancy are offered. Calculations and measurements of the ion fraction in these plasmas are also presented.

CP8.00023 Observations of an Ion Driven Instability in Non-neutral Plasmas Confined on Magnetic Surfaces. , Q. MARKSTEINER, T. PEDERSEN, J. BERKERY, J. MENDEZ, M. HAHN, P. ENNEVER, Columbia University, H. HIMURA, Kyoto Institute of Technology — The Columbia Non-neutral Torus (CNT) is a stellarator designed to confine non-neutral plasmas, including non-neutral ion-electron plasmas. When the ion density exceeds approximately 10% of the electron density in CNT, an instability is observed. The instability has a poloidal mode number of m = 1, despite the fact that CNT does not contain an m = 1 rational surface. The measured frequency of the instability decreases with increasing magnetic field strength, and increases with increasing radial electric field, suggesting that the instability is linked to the ExB flow of the plasma. The frequency does not, however, scale exactly as E/B, and it depends on the ion species that is introduced. These observations, along with the measured m = 1 poloidal mode number imply that the instability involves an interaction between ions, and electrons that are mirror trapped and therefore do not circulate toroidally. Results from a numerical code which follows the complex (and sometimes chaotic) motion of an ion in CNT are also presented.

CP8.00024 Pure Electron Equilibrium and Transport Jumps in the Columbia Nonneutral Torus , M. HAHN, T. SUNN PEDERSEN, Q.R. MARKSTEINER, J.W. BERKERY, Columbia University — The Columbia Non-neutral Torus (CNT) is a simple stellarator, which is being used to study electron rich plasmas. At very low neutral pressures the plasmas are pure electron plasmas. The equilibrium depends on electrostatic and transport effects.The dependence of the equilibrium on the characteristics of the electron source have been studied. The plasma may be created by a single negatively biased filament either on or off the magnetic axis, or by multiple filaments. The toroidal location of the emitter has also been varied. Because of the large toroidal variations of the magnetic field strength in CNT the toroidal location affects the ratio of passing versus trapped particles, which affects transport. For an emitting filament within the plasma the loss rate of electrons from the plasma is the same as the emission current. As parameters that increase transport are varied abrupt jumps in emission current occur. These jumps imply discontinuous changes in the confinement time. The jumps occur at specific values of the emission current, i.e. at specific transport rates. Other parameters that affect transport, such as neutral pressure and magnetic field strength, only affect the jumps to the extent that they affect transport. The jumps show hysteretic behavior indicative of regions in the current-voltage characteristic of the plasma-diode system with negative differential resistance.

CP8.00025 Installation and Operation of a Conducting Boundary in the Columbia Non-Neutral Torus , P.W. BRENNER, T. SUNN PEDERSEN, J.W. BERKERY, R.G. LEFRANCOIS, M.S. HAHN, Q.R. MARKSTEINER, Columbia University — The Columbia Non-Neutral Torus (CNT) is a compact stellarator, which is currently being used to study non-neutral plasmas confined on magnetic surfaces. Previously, confinement times up to 20 ms have been measured, limited in part by enhanced transport caused by potential variation along magnetic surfaces. Conducting meshes that conform to the last closed magnetic surface were recently installed in CNT. These meshes create an equipotential boundary at the last closed surface, improving the match between equipotential and magnetic surfaces as well as offering new non-intrusive methods to diagnose the plasma. The conducting mesh boundary is composed of 13 individual sectors that can act as probes. These probes can measure the decay of an induced image charge, plasma oscillations, or actively drive oscillations to diagnose the plasma properties. A description of the apparatus and the results of initial experiments are presented. A limiter probe surrounding the majority of a cross section has also been inserted to directly measure confinement by the decay of electron flux. Experiments have been completed demonstrating that electron flux to a point probe at the last closed flux surface accounts for less than 10 percent of all the electrons leaving the magnetic surfaces. These results and their implications for a limiter probe diagnostic will be discussed.

CP8.00026 Numerical Studies of Transport in the Columbia Non-Neutral Torus , BENOIT DURAND DE GEVIGNEY, THOMAS SUNN PEDERSEN, ALLEN H. BOOZER, Columbia University — The confinement of pure electron plasmas in the Columbia Non-neutral Torus (CNT) stellarator is limited by the presence of internal probes and electron-neutral collisions. The probes can be removed, so the transport of fundamental interest is the neoclassical transport associated with the electron-neutral collisions. This transport depends on the distance the electron trajectories deviate from the magnetic surfaces. The magnetic fields in CNT have not been optimized to minimize the deviation of trajectories from the surfaces. The reason is the electric potential is very large compared to the temperature, and the $E \times B$ drift dominates the magnetic drifts. In particular, the variation in the electric potential across the magnetic surfaces greatly reduces the radial drift of the electrons. However, unlike the situation in a quasi-neutral plasma, the electric potential also varies within the surfaces, which adds to the complexity of the trajectories and can increase the radial drifts. We have written a code using magnetic coordinates to integrate the electron drift trajectories in the electric and magnetic fields expected in CNT equilibria. A Monte-Carlo code including both electron-electron collisions and electron-neutral collisions will be used to determine if the plasma transport in CNT is neoclassical, how it depends on the electron density and how it is affected by the potential not being a function of flux only.

CP8.00027 Confinement Time Exceeding One Second in a Toroidal Electron Plasma , M.R. STONEKING, J.P. MARLER, BAO HA, J.C. SMONIEWSKI, Lawrence University — Pure electron plasmas ($n = 2 \times 10^7$ cm^{-3}, $a = 1.27$ cm, $R_p = 17.4$ cm) are confined for times exceeding one second in a new toroidal device, the Lawrence Non-neutral Torus II. The plasma is trapped in a 270° toroidal arc by application of gate potentials to sections of a sectored gold-plated toroidal boundary ($b = 3.81$ cm, $R_0 = 18$ cm). At base vacuum pressures below 10^{-8} torr and magnetic field strengths approaching 700 gauss, the $m = 1$ diocotron mode is excited by applying several cycles of rf near the resonant frequency to a section of the wall. The $m = 1$ frequency, which is approximately proportional to the trapped charge, decays on a three second timescale, a confinement time that exceeds by at least an order of magnitude the confinement observed in all other toroidal traps for non-neutral plasmas. Numerical simulations that include toroidal effects are employed to accurately extract plasma charge and $m = 1$ mode amplitude from the experimental data. Future work will include attempts to withdraw the electron source in order to study confinement in a full torus. This work is supported DOE-NSF Grant 0317412.

CP8.00028 Magnetic Field Dependence of the Diffusion Coefficient in Asymmetry-Induced Transport[1] , D.L. EGGLESTON, J.M. WILLIAMS, Occidental College — The dependence of the asymmetry-induced radial particle flux Γ on axial magnetic field B is complicated by the fact that the field enters the physics in at least two places: in the asymmetry-induced first order radial drift velocity $v_r = E_\theta/B$ and in the zeroth order azimuthal drift velocity $v_\theta = E_r/B$. To separate these, we assume the latter always enters the physics in the combination $\omega - l\omega_R$ where $\omega_R(r) = v_\theta/r$ is the column rotation frequency and ω and l are the asymmetry frequency and azimuthal mode number, respectively. We then select from a Γ vs r vs ω data set those points where $\omega - l\omega_R = 0$, thus insuring that any function of this combination is constant. When the selected flux is plotted versus the density gradient ∇n, a roughly linear dependence is observed, showing that our assumption is valid and that we have isolated the diffusive contribution to the transport. The slope of a least-squares fitted line then gives the diffusion coefficient D. Varying the magnetic field, we find $D \propto B^{-1.33\pm0.12}$. This does not match the scaling predicted by resonant particle transport theory[2].

[1]Supported by DOE grant DE-FG02-06ER54882 and Occidental College
[2]D.L. Eggleston and T.M. O'Neil, Phys. Plasmas 6, 2699 (1999).

CP8.00029 Limits of Particle-beam Extraction from Single-Component Plasmas[1] , T.R. WEBER, J.R. DANIELSON, C.M. SURKO, University of California, San Diego — Recently, a non-destructive technique was developed to create finely focused beams of electrons (or positrons) from single-component plasmas confined in a Penning-Malmberg trap[2]. This technique exploits the fact that the plasma potential is largest near the plasma center; thus, when the confining potential at one end is carefully lowered, a beam is formed that is composed only of particles escaping from the region near r = 0. Here, we investigate the limits of this technique. A simple model for beam extraction is described that predicts a Gaussian beam profile when the number of extracted particles is small. This expression gives a minimum beam diameter of four Debye lengths (full width to 1/e) and is verified using electron plasmas over a broad range of plasma temperatures ($0.05 < T < 2$ eV) and densities ($0.06 < n < 2\times10^{10}$). Numerical calculations are used to predict the profiles of beams with large numbers of extracted particles, and they are in fair agreement with the measurements. The extraction of over 50% of a trapped plasma in a train of nearly identical beams is demonstrated. Applications to create state-of-the-art positron beams, including the possibility of extracting the beam from the magnetic field to form an electrostatic beam, are also discussed.

[1]This work supported by NSF, grants PHY 03-54653 and PHY 07-13958.
[2]J. R. Danielson et al., Appl. Phys. Lett. **90**, 081503 (2007).

CP8.00030 Attracting Fixed Points for Radially Compressed Single-Component Plasmas[1] , J.R. DANIELSON, C.M. SURKO, M.W. ANDERSON, T.M. O'NEIL, University of California, San Diego — Rotating electric fields are used to compress electron plasmas confined in a Penning-Malmberg trap using the so-called rotating wall (RW) technique[2]. Over a broad range in RW frequency, plasmas can be compressed until the $E \times B$ rotation frequency, $\omega_{\rm E}$ (with $\omega_{\rm E} \propto n$, the plasma density), approaches the applied frequency, $\omega_{\rm RW}$. Bifurcation and hysteresis are observed between low-density and high-density steady states as a function of the applied RW electric field amplitude and frequency. Here, models of the drive and drag torques are used to describe the stable, attracting fixed points of the system. Key ingredients are a drag torque due to a plasma-mode resonance, driven by static trap asymmetries, and a RW drive torque that passes rapidly through zero as $\omega_{\rm E}$ approaches $\omega_{\rm RW}$. A number of tests of the model are described, including perturbation experiments to confirm the nature of the RW torque and to measure its magnitude near the high-density fixed point. Open questions for future research, including a possible thermodynamic model to describe the plasma dynamics, are discussed.

[1]This work supported by NSF, grants PHY 03-54653 and PHY 07-13958.
[2]J. R. Danielson and C. M. Surko, Phys. Rev. Lett. **95**, 035001 (2005); and Phys. Plasmas **13**, 055706 (2006).

CP8.00031 A Multicell Trap for Positron Storage[1] , C.M. SURKO, J.R. DANIELSON, T.R. WEBER, University of California, San Diego — We describe several techniques necessary for the practical implementation of a multicell Penning-Malmberg trap[2,3] designed to increase positron storage by orders of magnitude (e.g., to particle numbers N $\geq 10^{12}$). Experiments are done using test electron plasmas. A technique is described to move plasmas across the confining magnetic field and dump them at specific radial and azimuthal locations. Techniques are deomonstrated to fill and operate two in-line plasma cells simultaneously and to use 1 kV confinement potentials to trap 3×10^{10} particles. These experiments establish the capability to create, confine, and manipulate plasmas with the parameters required for a multicell trap, namely N $\geq 10^{10}$ in a single cell with temperatures $\leq$ 0.2 eV, plasma lengths $\sim$ 10 cm, and radii $\sim$ 0.2 cm. The design of a new structure to test the confinement of plasmas in off-axis cells is presented, as well as an improved design for a multicell positron trap for 10^{12} particles. Potential applications, including prospects for a portable positron trap (i.e., to replace conventional isotope and accelerator-based sources) will also be discussed.

[1]This work supported by DARPA grant HR0011-05-1-0041, and NSF grants PHY 03-54653 and PHY 07-13958.
[2]J. R. Danielson *et al.*, Phys. Plasmas **13**, 123502 (2007).
[3]C. M. Surko *et al.*, Rad. Phys. Chem. **68**, 419 (2003).

CP8.00032 SPHEROMAKS AND MCX —

CP8.00033 SSPX Achievements and Future Directions for Spheromak Research , H.S. MCLEAN, R.D. WOOD, D.N. HILL, E.B. HOOPER, B. HUDSON, R.J. JAYAKUMAR, L.L. LODESTRO, J.M. MOLLER, C.A. ROMERO-TALAMAS, T.A. CASPER, B.I. COHEN, T.K. FOWLER, L.D. PEARLSTEIN, D.D. RYUTOV, J.C. ORTIZ, J.H.T. CLEMENTSON, Lawrence Livermore National Laboratory, J. KING, E.C. MORSE, UC Berkeley, E.D. MEZONLIN, J.A. JOHNSON III, Florida A&M Univ., C.R. SOVINEC, UW-Madison — The Sustained Spheromak Physics Experiment (SSPX) has achieved significant results including peak electron temperature $T_e > 500$eV, magnetic field B > 1T, plasma current $I_p \sim$1MA, and core electron thermal diffusivity $\chi_e < 10$ m^2/sec. Several new operating regimes have demonstrated more efficient building and sustaining of self-organized spheromak magnetic fields. A vigorous collaborative campaign to develop new capabilities for the NIMROD 3D resistive MHD code and benchmark against SSPX data has improved physics understanding and predictive capability. Recent results indicate neutral beam injection is an important next step for evaluating energy confinement and exploring NBI current drive as a means of dynamo-free sustainment. Goals identified for next-generation spheromaks include longer pulses, higher flux amplification through variable bias flux operation, and thinner walls with active feedback control of external tilt/shift modes. Work performed under the auspices of the US DOE by UC-LLNL under contract W-7405-ENG-48.

CP8.00034 Magnetic Field Build-up in SSPX[1] , R.D. WOOD, B.I. COHEN, D.N. HILL, E.B. HOOPER, L.L. LODESTRO, H.S. MCLEAN, J.M. MOLLER, C.A. ROMERO-TALAMÁS, Lawrence Livermore National Laboratory — Magnetic field build up experiments in SSPX using the modular capacitor bank have produced discharges (extended formation) with the highest edge poloidal fields and multi-pulse discharges that continue to build magnetic field in a stepwise manner. The ratio of B_p/I_{gun} for the multi-pulse discharges (~0.9T/MA) exceeds the value of B_p/I_{gun}=0.65T/MA obtained with a standard discharge (fast formation followed by sustainment discharge). As suggested by simulations, the higher ratio with the new injected current waveforms may reflect the longer total formation pulse duration (building to higher field due to the longer current pulse) than previous discharges. Recent results from multi-pulse and extended formation experiments and near mega-ampere injected current discharges will be presented.

[1]Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W7405ENG48.

CP8.00035 Electron Temperature Measurements and Energy Transport in SSPX , B.F. HUDSON, T.A. CASPER, E.B. HOOPER, R.J. JAYAKUMAR, L.L. LODESTRO, H.S. MCLEAN, J.M. MOLLER, C.A. ROMERO-TALAMAS, R.D. WOOD, Lawrence Livermore National Laboratory — Time-resolved measurements ($\leq$100 μs) have been made with a multi-pulse Thomson scattering diagnostic in the SSPX spheromak experiment, to obtain radial electron density and temperature profile during plasma formation and sustainment. In most discharges three regimes are observed with respect to T_e and n_e evolution. Initially there is a cold (<100 eV) formation phase, followed by a hollow T_e profile with maximum temperatures 100-200 eV, and a final heat-up and cool-down phase where we obtain the highest plasma temperatures (350+ eV). The transition from hollow to peaked T_e is quite sharp (~50 μs) and the recent upgrade to double-pulse Thomson scattering (~40 μs between pulses) facilitates capturing this transition. We also present simulations using the CORSICA code where the equilibrium is kept fixed and the discharge is evolved to observe the change in temperature profiles for different transport coefficients. In addition, electron transport and heating will be correlated with measured MHD mode activity. Temperature and density measurements during multi-pulse coaxial gun-current operation will also be presented. * Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W–7405–ENG–48.

CP8.00036 Predictive capability for whole-device spheromak MHD physics[1] , E.B. HOOPER, B.I. COHEN, LLNL, SSPX TEAM — Resistive, single-fluid (NIMROD) MHD simulations reproduce many SSPX results and contribute to our understanding of spheromak physics. Simulation is benchmarked to experiment including sensitivity to simulation parameters: viscosity, maximum toroidal mode number, finite-element number, density, and particle diffusivity. Quantities comparing well with experiment include gun voltage, thresholds for spheromak formation and sustainment, and magnetic field strength and time evolution. MHD mode amplitudes and q-profiles are moderately sensitive. Precise time histories, e.g., the rate of reconnection events, are more sensitive but have little effect on average quantities, e.g. magnetic field strength. Experimental Te is 20-50% higher than simulations – flux surface quality is very sensitive to small changes in mode activity. The results provide confidence in simulations of upgrades or advanced spheromak experiments. Refs.: C.R. Sovinec, et al., Phys. Rev. Lett. **94**, 035003 (2005); B.I. Cohen, et al., Phys. Plas. **12**, 056106 (2005); E.B. Hooper et al., Phys Plas. **12**, 092503 (2005); E.B. Hooper, et al., Nucl. Fusion (in press).

[1]Work supported by U.S. DOE under Contract No. W-7405-ENG-48 at UC LLNL.

CP8.00037 Linear MHD Stability Analysis of the SSPX Spheromak[1] , R. JAYAKUMAR, B.I. COHEN, E.B. HOOPER, L.L. LODESTRO, H.S. MCLEAN, L.D. PEARLSTEIN, R. WOOD, Lawrence Livermore National Lab, Livermore, CA, A.D. TURNBULL, General Atomics, San Diego, CA, C. SOVINEC, University of Wisconsin, Madison, WI — Good correlation between the toroidal mode numbers of measured magnetic fluctuations in high temperature SSPX plasmas and presence of low-order rational surfaces in the reconstructed q profiles, suggests that the quality of magnetic surfaces in SSPX is sufficiently good for applying standard linear MHD stability analyses. Previously we have reported on benchmarking the code NIMROD against GATO, with good agreement in growth rates for ideal-MHD internal kinks and an external kinks with no current on open field lines (for equilibria imported from the code Corsica). Recent stability analyses also show that presence of low order rational surfaces causes internal modes to become unstable. We will report on the progress in applying these tools for assessing beta limits in SSPX, using NIMROD analyses including current on open field lines and for comparison with experiments.

[1]Work performed at UC Lawrence Livermore National Laboratory under the auspices of US Department of Energy Contract No. W-7405-ENG-48.

CP8.00038 Neutral Beam Current Drive in Spheromak plasma and plasma stability , L.D. PEARLSTEIN, R.J. JAYAKUMAR, B. HUDSON, D.N. HILL, L.L. LODESTRO, H.S. MCLEAN, T.K. FOWLER, T.A. CASPER, SSPX TEAM — A key question for the Sustained Spheromak Physics Experiment (SSPX) is understanding how spheromaks can be sustained by other current drive tools such as neutral beam current drive. Another question is whether the present relationship between current and maximum spheromak magnetic field (plasma beta) is related to Alcator-like ohmic confinement limit or is a stability limit. Using the code CORSICA, the fraction of neutral beam current drive that can be achieved has been calculated for different injection angles with a fixed equilibrium. It is seen that relaxing the equilibrium with this drive simply drives the core safety factor to low values. Other equilibria where the NBI may give aligned current drive are being explored. Free-boundary equilibria calculations are underway to see what hyper-resistivity model gives the observed sustained SSPX performance and include that in the NBI calculations. Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

CP8.00039 Flux amplification in SSPX[1] , LYNDA LODESTRO, E.B. HOOPER, R.J. JAYAKUMAR, L.D. PEARLSTEIN, R.D. WOOD, H.S. MCLEAN, LLNL, SSPX TEAM — Flux amplification—the ratio of poloidal flux enclosed between the magnetic and geometric axes to that between the separatrix and the geometric axis—is a key measure of efficiency for edge-current-driven spheromaks. With the new, modular capacitor bank, permitting flexible programming of the gun current, studies of flux amplification under various drive scenarios can be performed. Analysis of recent results of pulsed operation with the new bank finds an efficiency $\sim$ 0.2, in selected shots, of the conversion of gun energy to confined magnetic energy during the pulses, and suggests a route toward sustained efficiency at 0.2. Results of experiments, a model calculation of field build-up, and NIMROD simulations exploring this newly suggested scenario will be presented.

[1]Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W–7405–ENG–48.

CP8.00040 Measurements of spheromak formation and field buildup at SSPX using a double magnetic probe array , C.A. ROMERO-TALAMAS, O.O. OHIA, R. JAYAKUMAR, Lawrence Livermore National Laboratory, Livermore, CA 94550, SSPX TEAM — A specially designed magnetic probe consisting of two linear arrays that measure Bx, By, and Bz, is being used to investigate magnetic evolution during spheromak formation, and during multiple gun current pulses on top of a baseline current at SSPX. The measurements reveal that at the start of each pulse there is a time lag in the magnetic response of the closed flux region, while the open flux (intercepting the gun electrodes) responds immediately. This is interpreted as the time to build enough helicity on the open flux, before reconnecting and adding flux to the closed surfaces. Magnetic reconstructions after pulsed buildup using CORSICA show good agreement with the data. A code that simulates the magnetic field from current-carrying flux ropes is used to reproduce the field measured during flux buildup. The code includes an optimization routine that finds the rope shape that best fits the data in order to estimate helicity in the open flux. Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

CP8.00041 Stereo Imaging as a Diagnostic in SSPX , J.C. ORTIZ, C.A. ROMERO-TALAMAS, Lawrence Livermore National Laboratory, Livermore, CA 94550, SSPX TEAM — A stereoscopic imaging diagnostic to provide three-dimensional information of plasma behavior during spheromak formation is being designed and constructed at SSPX. The diagnostic consists of two convex mirrors, macor/stainless steel mounts, a high-speed camera and a telephoto lens. Using a titanium adhesion layer, a thin gold layer is applied to a stock lens providing greater than 95 percent reflectivity at 650nm and a wide field of view. The mirrors and mounts will be under vacuum while the camera and telephoto lens will be located outside the spheromak chamber. The high-speed camera will view both mirrors in the vacuum chamber and provide two images per plasma shot. Each image will be divided such that each mirror will comprise one image. Software will be used to overlay the images to provide a three-dimensional effect. The depth of objects inside the flux conserver can be found as a function of the overlap of the two images. Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

CP8.00042 Ion Doppler Spectroscopy Measurements on SSPX , J. KING, E.C. MORSE, UC Berkeley/LLNL, H.S. MCLEAN, R.D. WOOD, J.M. MOLLER, Lawrence Livermore National Laboratory, SSPX TEAM — The Sustained Spheromak Physics experiment (SSPX) at Lawrence Livermore National Laboratory is performing experiments pertaining to formation and sustainment of spheromak plasmas. An existing high resolution Ion Doppler Spectrometer (IDS) has been reactivated to measure impurity ion temperature and velocity. The IDS is composed of an Instruments S.A. HR 1000 Czerny-Turner monochromator with diffraction grating line density of 2400 lines/mm, which allows for first order spectra between 300 and 600nm. Combined with a 16 channel photomultiplier tube assembly in place of the output slit, a spectral width of 5 nm over 16 individual time-resolved spectra is achieved. By observing the Doppler broadening and shifting of OIII and OIV lines in the plasma, time resolved ion temperature and flow information can be investigated. As an added check, a separate Ocean Optics HR4000 spectrometer is used to obtain a time-integrated spectrum of each shot, in order to verify the presence of oxygen line radiation. Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W–7405–ENG–48.

CP8.00043 EUV spectroscopy on the SSPX spheromak , J.H.T. CLEMENTSON, P. BEIERSDORFER, R.D. WOOD, Lawrence Livermore National Laboratory, SSPX TEAM — EUV plasma spectroscopy is one of the diagnostics used at the Sustained Spheromak Physics Experiment (SSPX) to study plasma impurity ions. SSPX produces hydrogen plasmas of densities around 10^{14} cm^{-3} with peak electron temperatures from 10 eV up to 550 eV, thus covering a broad range of plasma conditions. The diagnostic consists of a grating spectrometer with a field of view through the magnetic axis at the mid-plane of the spheromak. It employs a spherical flat-field grating, covering the spectral region of 25 – 400 Å with a resolution of 1 Å. The recording of spectra is done using a Photometrics CCD camera. Several charge states of low-Z elements have been identified, notably B, C, N and O. Of the heavier elements, Cu and Ti are found in the machine, again in a variety of charge states. We are exploring the possibility of injecting metallic compounds, such as tungsten and iron, of interest to fusion engineering, atomic theory and atomic astrophysics. Work at UC Lawrence Livermore National Laboratory was performed under the auspices of the US Department of Energy under Contract No W-7405-ENG-48.

CP8.00044 Correlation between gun current and ion temperature in SSPX plasma , E.D. MEZONLIN, J.B. TITUS, J.A. JOHNSON III, Florida A&M University, Tallahassee, Fl, J.M. MOLLER, E.B. HOOPER, H.S. MCLEAN, B. HUDSON, C.A. ROMERO-TALAMAS, R.D. WOOD, Lawrence Livermore National Laboratory, SSPX TEAM — SSPX diagnostics include ion temperature, Ti, from a Compact Neutral Particle Analyzer, electron temperature, Te, from Profile Thomson Scattering and time resolved soft X-ray ratios, and electron density, ne, from CO2 laser interferometry. We examine the correlations between these parameters and the SSPX gun current, in shots with multiple pulses of helicity injection. The measurements show that any increase in the gun current in an individual shot coincides with an increase in the ion temperature and a decrease in electron temperature and density. We also notice that an increase of helicity injection from shot to shot seems not to affect the ion temperature but influences greatly the neutral flux. This may be due to high gun current, which opens the field lines allowing more ions to escape confinement and then migrate to edge where they can interact with the neutrals. Work supported under the auspices of the US DOE by UCLLNL under contract W-7405-ENG-48.

CP8.00045 Correlations of Turbulent Magnetic Field Parameters with Electron and Ion Temperature Measurements in SSPX Plasmas[1] , J.A. JOHNSON III, J.B. TITUS, E.-D. MEZONLIN, Florida A&M University, J.M. MOLLER, E.B. HOOPER, H.S. MCLEAN, B. HUDSON, C.A. ROMERO-TALAMAS, R.D. WOOD, Lawrence Livermore National Laboratory, FLORIDA A&M UNIVERSITY COLLABORATION, LAWRENCE LIVERMORE NATIONAL LABORATORY COLLABORATION — A new approach to turbulence physics provides a new context for turbulent diagnostic parameters in SSPX magnetic field fluctuations. Using the diagnostics for: ion temperature, Ti, from a Compact Neutral Particle Analyzer; electron temperature, Te, from Profile Thomson Scattering and time resolved soft X-ray ratios; and electron density, ne, from CO2 laser interferometry, we can now study the impact of variations in the SSPX helicity injection during a single shot on magnetic field fluctuations. We will report on changes in the complexity, changes in the rate of energy transfer through the various lengths scales, changes in characterizing fluctuation frequencies along with changes in the turbulent energy in the magnetic field fluctuations for a variety of shots with special attention on the relationships between these changes and the helicity, electron temperature and ion temperature determinations.

[1]Research supported in part by grants from DOE and NSF.

CP8.00046 Correlation of Soft X-ray Emission with Thompson Scattering Measurements of Electron Temperature in SSPX[1] , D.F. MONTEZ, B.F. HUDSON, H.S. MCLEAN, C.A. ROMERO-TALAMAS, R.D. WOOD, D. CORRELL, LLNL, SSPX TEAM — In an effort to measure time-resolved changes in the plasma temperature over the 100 – 300 eV range, soft X-ray photodiodes have been installed in SSPX. Two sensors with different quantum efficiency versus frequency distributions are aligned along a common chord tangent to the magnetic axis of the plasma. Analysis of the ratio of the two signals offers time-resolved insight into Bremsstrahlung soft X-ray emissions, which are a function of the chord integrated electron temperature. Results of a numerical model for the soft X-ray ratio are compared to experimental measurements. Correlation of the temperature data from these sensors to the diagnostic data taken from a Thomson scattering apparatus will be presented.

[1]Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

CP8.00047 Overview of results from the Caltech Spheromak Formation, Astrophysical Jet, and Solar Coronal Loop Simulation Experiments[1] , P.M. BELLAN, D. KUMAR, G.S. YUN, A.L. MOSER, E.V. STENSON, R.J. PERKINS, S.K.P. TRIPATHI[2], Caltech — These experiments involve magnetized plasma guns with (i) coaxial symmetry (spheromak formation studies, astrophysical jet simulation) and (ii) bipole symmetry (coronal loop simulation experiment). Both experiments form MHD jets that fill magnetic flux tubes linking the electrodes with plasma ingested from sources at the electrodes. Diagnostics include high-speed photography, HeNe interferometry, optical spectroscopy (Stark broadening density, Doppler velocity, line ratio temperature), color-coded imaging of different gases, and magnetic probes. The observed flux tubes are bright, dynamic, plasma-filled, and collimated. Collimation is interpreted as due to a shock-like pile-up of azimuthal magnetic flux frozen into the current-carrying jet. Observations include (i) dependence of jet velocity on electric current, (ii) what happens when a jet impacts a gas target, (iii) spatial dependence of jet velocity and density, (iv) a non-MHD particle orbit instability. Jet ingestion of plasma has been vividly imaged using different gases on the cathode and anode of the coronal loop experiment.

[1]supported by USDOE and AFOSR
[2]now at UCLA

CP8.00048 Plasma tubes becoming collimated as a result of MHD pumping[1] , G.S. YUN[2], P.M. BELLAN, Caltech — Long collimated magnetized plasma tubes commonly occur in nature, ranging from solar coronal loops (10^{7-8} m) to astrophysical jets (10^{15-22} m). Plasma jets produced by the Caltech planar spheromak gun develop structures bearing a striking resemblance to these natural plasma tubes. We report detailed new experimental measurements† of gun-produced plasma jets that support a recently-proposed MHD pumping model‡ as a universal collimation mechanism. Time- and space-resolved spectroscopic measurements show (i) suprathermal flow (30–50 km/s), (ii) large density amplification from 10^{17} to 10^{22-23} m^{-3} in an Alfvénic time scale, and (iii) flow slowing down and mass accumulation at the jet front. High-speed camera imaging shows that the collimation occurs at the jet front. These observations are consistent with the MHD pumping model which predicts (i) magnetic pumping of plasma particles from a high-density source region into a flux tube and (ii) tube collimation if the flow slows down leading to accumulation of mass and thus concentrating the azimuthal magnetic flux frozen in the mass flow (i.e., increasing the pinch force). †G. S. Yun, PhD thesis (2007) ‡P. M. Bellan, Phys. Plasmas 10(2), 1999 (2003).

[1]Supported by US DoE.
[2]Current address: Lam Research Corp., Fremont, CA.

CP8.00049 Flow velocity measurements and X-ray imaging of merging flux tubes[1] , D. KUMAR, P.M. BELLAN, Caltech — At the Caltech Spheromak Experiment, eight different flux tubes merge to form a collimated axially symmetric plasma jet. The plasma flow velocity in the collimated jet was calculated using the time of flight measurement from the density trace of a heterodyne He-Ne interferometer*. The velocity directly correlates with the toroidal magnetic field created by the axial plasma current through the jet. The plasma jet ingests magnetic helicity and energy into bulk plasma. A longer plasma jet has a larger inductance as it links more flux across itself. Since magnetic energy scales linearly with the plasma inductance, a faster plasma jet is expected to have higher magnetic energy. An energy analysis of the plasma jet is currently underway. The analysis should be applicable to other axially symmetric plasma experiments as well. Magnetic reconnection drives the merging process of the individual flux tubes into the single jet. In the experiment, reconnection is also concurrent with X-ray emission in the EUV/soft X-ray band. A high speed X-ray imaging system is being developed (exposure time $10-300$ ns) for imaging the plasma in the EUV band. The small exposure time is expected to give insights into the fast plasma dynamics during the merging of flux tubes.
*D. Kumar, P. M. Bellan, Rev. Sci. Instrum. 77, 083503 (2006)

[1]Supported by U.S. Department of Energy.

CP8.00050 Overview of the Helicity Injected Torus Program , BRET THOMAS STEWART, A.J. REDD, T.R. JARBOE, R.Z. ABOULHOSN, C. AKCAY, W.T. HAMP, G. MARKLIN, B.A. NELSON, R.G. O'NEILL, R. RAMAN, P.E. SIECK, R.J. SMITH, J.S. WROBEL, University of Washington, Seattle, Washington — The Helicity Injected Torus with Steady Inductive Helicity Injection (HIT-SI) spheromak experiment [Jarboe, Fus.Tech., v.36, p.85 (1999)] addresses critical research areas for spheromak formation and sustainment, including current drive, high-beta operation, confinement quality, and efficient steady-state operation. HIT-SI has a "bow-tie" shaped, axisymmetric confinement region with a major radius of 0.33 m, and an axial extent of 0.57 m. Attached to the confinement region are two half-torus helicity injectors, one mounted on each end of the flux conserver. HIT-SI has produced up to 30 kA of toroidal current in spheromaks generated using less than 4 MW of applied power, demonstrating that Steady Inductive Helicity Injection can create and sustain discharges with modest power requirements. HIT-SI has recently been repaired and upgraded, with an improved flux conserver, higher helicity and power injection, better diagnostic coverage, and an improved plasma-facing insulating surface. HIT-SI operational and diagnostic improvements, and corresponding physics studies, will be summarized.

CP8.00051 The physics of steady-state CHI in an ST , A.J. REDD, T.R. JARBOE, W.T. HAMP, B.A. NELSON, R.G. O'NEILL, R. RAMAN, R.J. SMITH, University of Washington, Seattle, WA USA — The HIT-II spherical tokamak (major radius 0.30 m, minor radius 0.20 m) is capable of using Coaxial Helicity Injection (CHI) to form and sustain low-aspect-ratio axisymmetric discharges. The physics of CHI-driven HIT-II discharges is now fairly well understood, with intuitively derived models and scalings matching the entire HIT-II experimental database. These physics results include: (1) open-flux CHI discharges are current sheets attached to the electrodes, and the sheet thickness is proportional to the inter-electrode distance; (2) the injector current and open-flux toroidal current match the models, including the independence of open-flux current Ip from the TF coil current; (3) thin-sheet CHI discharges can exhibit poloidal flux amplification and buildup of toroidal current beyond the open-flux results; (4) the mechanism for poloidal flux amplification is injector-based reconnection activity (not a coherent mode in the confinement region) requiring a minimum rotation of the magnetic field in the injector region; and (5) flux-amplification discharges exhibit features of a confined plasma core. Flux-amplification discharges in HIT-II are strongly paramagnetic, have total Ip as high as 350 kA, and exhibit flux amplification in both low-TF and high-TF regimes. These physical results will be explained in detail, as well as the key parameters, scalings, and thresholds.

CP8.00052 Evidence of closed flux during CHI formation of a spherical tokamak in the HIT-II experiment , W.T. HAMP, T.R. JARBOE, R. RAMAN, A.J. REDD, B.A. NELSON, R.G. O'NEILL, R.J. SMITH — The Helicity Injected Torus - II (HIT-II) experiment has demonstrated current drive by transformer action (OH), Coaxial Helicity Injection (CHI) and combinations of both. The electron temperature and density profiles of plasmas in HIT-II are measured by multi-point Thomson scattering (MPTS), and magnetic equilibria are reconstructed with EFIT. Internal probing of relaxed CHI discharges shows significant poloidal flux amplification. EFIT reconstructions of relaxed CHI discharges indicate significant closed flux, and poloidal flux increase in time. CHI initiated OH plasmas generate closed flux during the purely CHI startup. Temperature profiles of purely CHI plasmas do not match open flux models. When CHI is added to an ohmic plasma, the edge temperature drops by 75%, and the edge density doubles, while the core plasma properties remain similar to OH only discharges, indicating a transport barrier. The simplest explanation of the data is the formation and sustainment of closed flux during CHI current drive. The limitations on HIT-II CHI discharges are discussed, suggesting refinements to future experiments.

CP8.00053 Nimrod Simulations of Decaying and Driven HIT-SI Plasmas , CIHAN AKCAY, CHARLSON C. KIM, GRIFF O'NEILL, TOM R. JARBOE, BRIAN A. NELSON, University of Washington, VALERIE A. IZZO, General Atomics — The Steady Inductive Helicity Injected Torus (HIT-SI) is a spheromak that uses two semi-toroidal injectors to provide steady inductive helicity injection (SIHI), which produces and sustains a spheromak with significant toroidal current by generating poloidal flux using relaxation current drive. NIMROD's resistive MHD model was employed in conjunction with flux injector boundary conditions to simulate HIT-SI operation. This computational model was employed to explore the effects of SIHI and Lundquist number (S) on sustained HIT-SI plasmas. Preliminary computational results showed very little plasma current formation at the Lundquist numbers comparable to that of the experiment (∼5-10), a result that is in poor agreement with the experiment. To check these results, work has been undertaken to upgrade the existing computational model and to transfer it over to the newer version of NIMROD. Of particular interest are the improved resistive MHD and resistive MHD with the Hall term. The results of these simulations are to be compared with the experimental data. We will present our efforts and progress in this direction.

CP8.00054 Magnetic Diagnostics on HIT-SI Experiment , R.J. SMITH, J.S. WROBEL, T.R. JARBOE, B.A. NELSON, A.J. REDD, C. AKCAY, W.T. HAMP, B.T. STEWART, University of Washington — The HIT-SI equilibrium flux conserver is a CrCu shell with a 100ms L/R time. Pol. and tor. B-dot probes are embedded in the shell with a plasma facing s.s. disk to provide high bandwidth measurements. An extensive calibration of the probes from 10-200kHz has been carried out. Based on these calibrations, the probes can be digitized directly with much greater sensitivity at higher frequencies. The calibration and analysis procedures for reducing the measurements and an overview of the magnetic measurements will be presented.

CP8.00055 Development of rotating magnetic field coil system in the HIST spherical torus device , T. YOSHIKAWA, Y. KIKUCHI, S. YAMADA, S. HASHIMOTO, T. NISHIOKA, N. FUKUMOTO, M. NAGATA, Univ. of Hyogo — Coaxial Helicity Injection (CHI) is one of most attractive methods to achieve non-inductive current drive in spherical torus devices. The current drive mechanism of CHI relies on MHD relaxation process of rotating kink behavior [1], so that there is a possibility to control the CHI by using an externally applied rotating magnetic field (RMF). We have recently started to develop a RMF coil system in the HIST spherical torus device. Eight coils are located above and below the midplane at four toroidal locations so that the RMF is resonant with $n = 1$ rotating kink mode driven by the CHI. In addition, the RMF coil set is installed inside a flux conserver of 5 mm thickness (cut-off frequency $\sim$ 170 Hz) so that the RMF penetrates into the plasma. The coil winding is made of 20 turns of enameled copper circular wires (1.5 mm^2 conductor cross section), covered with a thin stainless steal case of 0.5 mm thickness (cut-off frequency $\sim$ 710 kHz). The RMF system is driven by an IGBT inverter power supply (nominal current: 1 kA, nominal voltage: 1 kV) with an operating frequency band from 10 kHz to 30 kHz. The estimated amplitude of RMF neglecting effects of image current at the flux conserver is a few tens Gauss at around the magnetic axis. A preliminary experimental result will be shown in the conference. [1] M. Nagata, et al., Physics of Plasmas **10**, 2932 (2003).

CP8.00056 Ion flow measurements during the rotating kink behavior of the central column in the HIST device , S. YAMADA, T. YOSHIKAWA, S. HASHIMOTO, T. NISHIOKA, Y. KIKUCHI, N. FUKUMOTO, M. NAGATA, Univ. of Hyogo — Plasma flow is essentially driven in self-organization and magnetic reconnection process of compact spherical torus (ST) and spheromak in the helicity-driven systems. For example, when reversing the external toroidal field of ST, the direction not only of the plasma current but also of the toroidal ion flow is self-reversed during the formation of the flipped ST relaxed states. Mach probe measurement shows that the velocity of the ion flow reversed after the flip increases to about 20 km/s. We have been newly developing an ion Doppler spectrometer (IDS) system using a compact 16 or 64 channel photomultiplier tube (PMT) in order to measure the spatial profile of ion temperature and rotation velocity in the HIST device. The IDS system consists of a light collection system including optical fibers, 1 m-spectrometer and the PMT detector. The optical fibers covered with glass tubes are inserted into the plasma. The glass tubes can be rotated in the poloidal and the toroidal directions. The new IDS system will be applied to observations of ion temperature and plasma rotation in the flipped ST formation and in the MHD control of kinking behaviors of the central column by using the rotating magnetic field (RMF). Preliminary IDS results will be compared to those from Mach probe measurements in space.

CP8.00057 Interaction of Accelerated Compact Toroid with External Magnetic Fields , D.Q. HWANG, S.J. HOWARD, R.D. HORTON, S.E. BROCKINGTON, R.W. EVANS, R. KLAUSER, UC Davis, D. BUCHENAUER, W.M. CLIFT, Sandia National Lab — The potential use of accelerated compact toroids (SCT) to fuel magnetically confined fusion devices requires a clear understanding of the CT interaction with external magnetic fields. Previous experiment using simple probe diagnostics has illuminate the interaction physics [1]. With an array of new diagnostics, we will perform more detailed measurements of the interaction. With the new fast 2-D optical camera, the interaction in the target chamber can be systematically studied. The newly developed deflectometor can differentiate the effects on the main CT plasma versus the trailing plasma following the main CT. It is expected the external magnetic field will affect the magnetized CT differently than the un-magnetized trailing plasma. In addition the effect of the external magnetic field on the impurity ion in the CT will be studies using particle collection probes. In addition the oriental of the external field may tilt stabilize the CT after its detachment from the acceleration electrodes. *This work supported by U.S. DOE Grant DE-FG02-03ER54732.
[1] D.Q. Hwang, H.S. McLean, K.L. Baker, R.W. Evans, R.D. Horton, S.D. Terry, S. Howard, G.L. Schmidt, Nuclear Fusion, Vol. 40, No. 5, pg 897 (2000)

CP8.00058 Hall MHD Equilibrium of Accelerated Compact Toroids[1] , S.J. HOWARD, D.Q. HWANG, R.D. HORTON, R.W. EVANS, S.J. BROCKINGTON, University of California, Davis — We examine the structure and dynamics of the compact toroid's magnetic field. The compact toroid is dramatically accelerated by a large rail-gun Lorentz force density equal to $\mathbf{j} \times \mathbf{B}$. We use magnetic data from the Compact Toroid Injection Experiment to answer the question of exactly where in the system $\mathbf{j} \times \mathbf{B}$ has nonzero values, and to what extent we can apply the standard model of force-free equilibrium. In particular we present a method of analysis of the magnetic field probe signals that allows direct comparison to the predictions of the Woltjer-Taylor force-free model and Turner's generalization of magnetic relaxation in the presence of a non-zero Hall term and fluid vorticity.

[1]This work supported by U.S. DOE Grant DE-FG02-03ER54732.

CP8.00059 Plasma Density Gradient Profiles of Unconstrained CTs with an Array of Laser Deflectometers on CTIX , SAMUEL BROCKINGTON, UCDavis Electrical Engineering, DAVID HWANG, UCDavis Applied Science, ROBERT HORTON, STEPHEN HOWARD, RUSS EVANS, PETER BEIERSDORFER, Lawrence Livermore National Lab — The Compact Toroid Injection Experiment (CTIX) is a plasma accelerator which can create compact toroid (CT) plasmas of controllable density and velocity. A CT is constrained by conducting walls during acceleration, but can be accelerated into a larger viewing chamber where the CT becomes unconstrained and is allowed to travel through free space. Since a laser deflectometer is a non-invasive line-integrated plasma density gradient diagnostic, an array of laser deflectometers at the viewing section of CTIX could profile density gradients of passing CTs in two dimensions with perturbing the plasma. A survey of density gradient profiles in two dimensions of unconstrained CTs traversing free space was conducted with an array of four temperature controlled laser deflectometers. These profiles of plasma density gradient were then used to estimate CT density profiles and CT total mass.

CP8.00060 Magnetic Field Effects on Accelerator-Region Gas Puffing on CTIX[1] , ROBERT HORTON, University of California, Davis, DAVID HWANG, STEPHEN HOWARD, SAMUEL BROCKINGTON, RUSSELL EVANS — By puffing axially-localized neutral gas into the accelerator region of CTIX prior to plasma formation and acceleration, high compact-toroid (CT) densities have been obtained. As gas puff density is increased, eventually spontaneous plasma breakdown occurs in the accelerator region, resulting in plasmas with high density, but with unsuitable internal field structure, timing, and location. Motivated by experiments which demonstrate the controlling effect of even weak magnetic fields on plasma breakdown in the formation region, azimuthally-symmetric magnetic fields will be applied in the vicinity of the accelerator valve in an attempt to increase the amount of gas which can be puffed without spontaneous breakdown. The effects of the localized magnetic fields of various configurations will be systematically examined, with the purpose of determining a regime of high density and high gas utilization efficiency during CT density buildup, thereby improving the usefulness of CT injection for fueling, target-compression, and other applications.

[1]Work supported by USDOE Grant DE-FG02-03ER54732.

CP8.00061 Impurity Content of Compact Toroid Plasmas in CTIX[1] , D. BUCHENAUER, W.M. CLIFT, Sandia National Laboratories, S.J. HOWARD, R. KLAUSER, S.J. BROCKINGTON, R.W. EVANS, D.Q. HWANG, R.D. HORTON, University of California Davis — The Compact Toroid Injection Experiment (CTIX) produces a high density, high velocity hydrogen plasma which maintains its configuration in free space on a MHD resistive time scale. Repetitive injection of CT plasmas is being considered as a deep fueling technique for tokamaks such as ITER. In order to study the importance of impurities, several sets of silicon collector probes were exposed to the high velocity CT plasmas. Elemental analysis by Auger Electron Spectroscopy indicated the presence of oxygen, aluminum, iron, and copper in films up to 20 nm thickness (1000 CT interactions). Using a smaller number of CT interactions (10), implantation of the impurities was measured with depth profiling. The ordering of the range of the impurities (oxygen, aluminum, iron, copper) agreed roughly with TRIM calculations, however, the depth of the implants was less than that predicted for impurities moving with the CT velocity. Analysis of artificially introduced impurities and a discussion of the source of the intrinsic impurities will be discussed.

[1]Work supported by US DOE Contract DE-AC04-94AL85000 and U.S. DOE Grant DE-FG02-03ER54732.

CP8.00062 Preliminary experiment of high-speed gas flow generation by a compact toroid injection into a gas neutralizer , Y. ITO, D. LIU, T. SHOJI, R. NAKANISHI, N. FUKUMOTO, T. SEKIOKA, Y. KIKUCHI, M. NAGATA, Univ. of Hyogo — A supersonic gas jet injection has been considered to be a new technique for future reactor fuelling and disruption mitigation in tokamak devices [1]. We have recently started to investigate a production of high-speed gas flow by using a compact toroid (CT) injection into a hydrogen gas neutralizer. The electron density of the CT plasma is 1∼4 x10^{21} m^{-3}, and the CT speed is 30∼70 km/s in the preliminary experiment. The kinetic-energy measurements of ions and neutrals after the neutralization were carried out by using an electrostatic ion energy analyzer and time-of-flight technique. An enhancement of the H_β emission level, a significant decay of the CT plasma density and the magnetic field profile have been observed after the neutralization when the neutral pressure is about 10^{-3} Torr. It could be considered that high-energy neutral particles were generated by a charge exchange process from the CT plasma to the neutral particles.

[1] V. Rozhansky, et al., Nucl. Fusion **46**, 367 (2006).

CP8.00063 Spheromak merging studies in an oblate flux conserver in SSX[1] , M.R. BROWN, C.D. COTHRAN, D.H. COHEN, V. CHAPLIN, A.M. PHILLIPS, L.D. BOOKMAN, T. GRAY, M.J. SCHAFFER, Swarthmore College — Work is underway on a new oblate flux conserver for spheromak merging studies on SSX. The oblate flux conserver has a $0.5\ m$ inside diameter and $L = 0.28\ m$ with a $6\ mm$ copper wall. The outer electrodes mate to the flux conserver through a conical entrance region. The entire inner surface will be coated with tungsten. Initial studies will be performed with arrays of magnetic probes and ion Doppler spectroscopy (IDS). Fast magnetic probe arrays in quartz jackets with resolution of $1\ mm$ will be installed for magnetic reconnection studies at the midplane. Low spatial resolution magnetic probes will map the equilibrium structure. The SSX IDS instrument measures with $1\ \mu s$ or better time resolution the width and Doppler shift of either the nascent C_{III} impurity $229.7\ nm$ line or a doped He_{II} impurity $468.6\ nm$ line to determine the temperature and line-averaged flow velocity. Preliminary data will be compared with earlier merging results in a $0.4\ m$ diameter, $L = 0.6\ m$ length prolate copper flux conserver in SSX. In prior merging studies we have measured $T_i \geq 50\ eV$ and $T_e \geq 30\ eV$ after all plasma facing surfaces are cleaned with helium glow discharge conditioning. Transient electron heating is measured with a 4-channel soft x-ray array and a $0.2\ m$ vacuum ultraviolet spectrometer (C_{III} $97.7\ nm/C_{IV}$ $155\ nm$ line ratio).

[1]Work supported by DOE, NSF, and CMSO.

CP8.00064 Nonlinear driven resonance in magnetic self-organization and the feasibility of a spheromak reactor[1] , XIANZHU TANG, Los Alamos National Laboratory, ALLEN BOOZER, Columbia University — A Taylor relaxed plasma ($\mathbf{j} = k\mathbf{B}$ with k a constant) under external magnetic helicity injection encounters resonances in spatial frequencies of its force-free eigenmodes. Such driven resonance underlies the physics of magnetic self-organization and determines the flux amplification in laboratory helicity injection applications. Here we show that for partially relaxed plasmas where the deviation from the fully relaxed Taylor state, for example, a flux-dependent k, is a function of the normalized flux χ/χ_a with χ_a the poloidal flux at the magnetic axis, a modified driven resonance persists even if $k(\chi)$ has an order-unity variation across the flux surfaces. We will also explain why experimentally accessing such nonlinear resonance appears to hold the key for a potential spheromak reactor. Ref. X.Z.Tang, Phys. Rev. Lett. **98**, 175001 (2007).

[1]Work supported by DoE OFES.

CP8.00065 2D MHD simulations of the High to Ordinary Mode Transitions in MCX[1] , I. SHAMIM, C. TEODORESCU, P. GUZDAR, A. HASSAM, R. CLARY, R. ELLIS, R. LUNSFORD, IREAP, University of Maryand, College Park, MD, USA — The plasma in the Maryland Centrifugal Experiment (MCX) device makes an abrupt transition from a good confined state (H mode) to a poorly confined state (the O mode). To model this transition a 2D time-dependent MHD code is used to determine the dynamical equilibrium states of the MCX configuration. An additional momentum loss term is added to the system of equations to model the coupling of the plasma to the neutrals in the vicinity of the two insulators at the mirror throats. An input momentum source is treated as a control parameter to drive the poloidal rotation which in the machine is accomplished by the radial electric field and the ensuing ExB rotation. It is found that for small values of the source, the equilibrium state is not centrifugally confined enough and hence experiences additional drag from the neutrals in the vicinity of the insulators. However, at a critical forcing, the plasma makes an abrupt transition to a good centrifugally confined state in which the plasma has pulled away from the end insulator plates. As it pulls away the drags from the neutrals in the throat region decreases which further increases the rotation thereby leading to better centrifugal confinement. The good confined state is reached when the momentum source balances the diffusive damping.

[1]Work supported by DOE.

CP8.00066 Magnetic Fluctuation Measurements in MCX[1] , SEUNG CHOI, PARVEZ GUZDAR, RICHARD ELLIS, ADIL HASSAM, IREAP, University of Maryland, College Park, MD, USA — Initial results from magnetic probes on the Maryland Centrifugal eXperiment(MCX) provide details of the rotation and poloidal mode structure of magnetic fluctuations in the edge region. Eight magnetic coils placed azimuthally around the edge measure magnetic field changes in the axial direction during the plasma discharge. The auto and cross-correlation of the magnetic fields between the coils show that the magnetic fluctuations are dominantly convected by the ExB plasma rotation for several rotation periods before significant decorrelation. The rotation so inferred is in the $E \times B$ direction and its magnitude is consistent with earlier spectroscopic measurements on MCX. These findings help identify the dominant modes at the edge and indicate that there are a few low mode numbers that are dominant during the discharge. Also, the speed of rotation and fluctuation spectrum is found to change dramatically from the High Rotation (HR) state to a low rotation ordinary (O) state. In the near future, we plan to use probes which measure the magnetic field in all three directions near the edge of MCX. This will help us understand the magnetic structure and the basic instability in MCX.

[1]grants from DOE.

CP8.00067 Spectral Results of the Magnetic Fluctuations Observed in MCX, ILKER UZUN-KAYMAK, S. CHOI, R. CLARY, R. ELLIS, A. HASSAM, C. TEODORESCU, University of Maryland, College Park, MCX TEAM — The Maryland Centrifugal Experiment (MCX) is set up to study centrifugal confinement and supersonic rotation. MCX is a magnetic mirror machine with end fields up to 2T independent of the mid-plane magnetic field. A radial electric field created by biasing the inner electrode with respect to outer wall is used to drive azimuthal rotation, i.e., E x B rotation. Previously, a small number of Bdot coils have been employed at the edge of the plasma to investigate the modes of operation. Preliminary results show that there are dominant modes associated with the E x B rotation. In order to assess magnetic fluctuations and the E x B rotation fully, 25 Bdot coils mounted on various locations inside MCX are utilized. Here we present the analysis of the observed spectral modes by means of the power spectrum and the bispectrum to focus on the nonlinear coupling among various m-modes. We will also address low frequency magnetic field perturbations via proper filtering process.

CP8.00068 The Maryland Centrifugal Experiment(MCX)[1], RICHARD ELLIS, S. CHOI, M.R. CLARY, R. ELTON, A.B. HASSAM, R. LUNSFORD, C. TEODORESCU, I. UZUN-KAYMAK, University of Maryland, A. CASE, S. MESSER, D. WITHERSPOON, HyperV Technologies — We report new results on MCX : a) measurements of ion rotational velocity profiles show parabolic radial profiles that demonstrate shear in the plasma rotation exceeds the critical value for shear stabilization; b) measurements of the velocity profile also show the plasma may not be undergoing isorotation , a departure from ideal MHD; c) a new insulator has eliminated the transition from high-rotation (HR) mode to low rotation(O) mode; d) the scaling of maximum rotational velocity with applied voltage and B shows that rotational velocity is clearly limited from above by the Alfven velocity but determining if the critical ionization phenomena is operable is not conclusive. We also report on: a) plans to launch a plasma jet from a newly constructed gun to impart momentum directly to MCX and b) magnetic probe measurements of fluctuations at a variety of azimuthal, radial, and axial locations to evaluate MHD stability and its relation to velocity profiles. Plans for higher voltages and higher B fields will be discussed.

[1]Work supported by USDOE

CP8.00069 Progress on H_α at MCX, R. CLARY, S.H. CHOI, R. ELLIS, A. HASSAM, C. TEODORESCU, I. UZUN-KAYMAK, University of Maryland, MCX TEAM — The Maryland Centrifugal eXperiment uses a seven-chord H_α measurement system to measure absolute intensity levels of the Hydrogen Balmer-alpha line in a rotating plasma with mirror magnetic geometry. Recently, new mirror insulators were designed and implemented, resulting in suppressed O-mode operation. We present comparisons between H_α signals before and after the implementation of the new insulator. We also present progress in modeling neutral density for a rotating mirror geometry as well as relevant comparisons to experimental measurements on MCX. Lastly, we discuss upgrading the H_α measurement system to include a 16-chord mid-plane array.

CP8.00070 Experimental study on the velocity limits of magnetized rotating plasmas, CATALIN TEODORESCU, RYAN CLARY, RICHARD ELLIS, ADIL HASSAM, ILKER UZUN-KAYMAK, University of Maryland — An experimental study on the physical limits of the rotation velocity of magnetized plasmas is presented. A comprehensive campaign has been carried out on the MCX, a mirror magnetic field plasma rotating azimuthally, to ascertain what physical effects limit attempts to externally boost the velocity. The externally applied parameters that control the plasma characteristics – applied voltage, external magnetic field and fill pressure – are scanned across the entire available range of values. It is found that the plasma rotation velocity does not exceed the Alfven velocity, in complete agreement with the equilibrium requirements of magnetically confined plasmas. As the velocity approaches the average Alfven speed, further applied force does not result in an increase past this critical speed. Diamagnetic loop measurements show that the diamagnetically excluded flux increases as the square of the Alfven Mach number, as predicted by equilibrium MHD theory. Measured rotation velocities are also found to stay below the critical ionization velocity in hydrogen, a limit suggested by Alfven. However, an approach to a definite limit has not been proven yet largely because of voltage and magnetic field upper bounds dictated by the available experimental hardware.

CP8.00071 MFC DIAGNOSTICS –

CP8.00072 Study of magnetic dipole forbidden transitions in Large Helical Device and its application to impurity and α particle diagnostics in burning plasmas, SHIGERU MORITA, MOTOSHI GOTO, National Institute for Fusion Science, RYUJI KATAI, ILE-Osaka, MALAY CHOWDHURI, Graduate University for Advanced Studies, ATSUSHI IWAMAE, Kyoto University — Magnetic dipole forbidden (M1) transitions of Al (Z=13) to Xe (Z=54) emitted in visible and VUV ranges have been observed in Large Helical Device (LHD) and analyzed with level population calculation. It is found that the ratio of the M1 transition to usually used electric dipole (E1) transition gives clearly separated two ranges exhibiting density-independence and density dependence. Observation of orthogonal linearly polarized components of the M1 lines gives a completely different structure from the E1 transitions. Diagnostic applications to burning plasmas, i.e., impurity spectroscopy using the M1 transitions from high-Z elements such as Mo and W and alpha particle measurement using the ratio of the M1 to E1 transitions and the Zeeman-polarization technique are presented.

CP8.00073 Observation of Novel Instability by using Microwave Imaging Reflectometry in LHD[1], SOICHIRO YAMAGUCHI, YOSHIO NAGAYAMA, ZHONGBING SHI, National Institute for Fusion Science, YUICHIRO KOGI, ATSUSHI MASE, Art Science and Technology Center for Cooperative Research, Kyushu Univ. — A novel instability with higher harmonics has been observed in the Large Helical Device (LHD) by using Microwave Imaging Reflectometry (MIR). The instability appears during NBI or ICRH heating, and it is radially localized near the rational surface with the rotational transform of unity. The density fluctuation has a fundamental frequency of $1 \sim 10$ kHz which depends on the ion temperature. The frequency is several times higher than the diamagnetic frequency of the thermal ions, and is much lower than the frequency of the Alfven Eigen modes. The similar spectrum is also observed in the magnetic probe signals. It is suggested that the mode may be destabilized by the energetic ions and related to the pressure gradient of the thermal ions.

[1]This work is supported by the budgets of the National Institute for Fusion Science, NIFS06KEIN0021,NIFS07KEIN0021,NIFS07ULPP525.

CP8.00074 Magnetic Fluctuation Profile Measurement Using Optics of Motional Stark Effect Diagnostics in JT-60U[1], TAKAHIRO SUZUKI, AKIHIKO ISAYAMA, GO MATSUNAGA, TAKAAKI FUJITA, TOSHIHIRO OIKAWA, YUTAKA KAMADA, Japan Atomic Energy Agency — Motional Stark effect (MSE) diagnostics in JT-60U works as polarimeter to measure the pitch angle of magnetic field as well as beam-emission-spectroscopy (BES) monochromator simultaneously at 30 spatial channels. Fluctuation in the BES signal contains fluctuations in plasma density and pitch angle. In a high beta plasma with MHD activity, density fluctuation is measured at the same frequency as the n=1 magnetic fluctuation measured by pickup-coils outside the plasma. With correlation analysis of the BES signals, the density fluctuation profile is not only inverted near q=2 surface measured by the MSE, but also inverted at opposite toroidal angles at the same radial position. Thus, it is reasonably concluded that the fluctuation is induced by rotating magnetic islands spatially localized about q=2 surface. In the discharge, fluctuation at the beat frequency ($f_{\mathrm{PEM}} \pm f_{\mathrm{n}}$) of pitch angle measurement (f_{PEM}) and density fluctuation (f_{n}) shows a signature of pitch angle fluctuation. The spatial structure of the pitch angle fluctuation is discussed.

[1]Work supported by Grand-in-Aid for Young Scientists (B) No. 18760650 from MEXT.

CP8.00075 Fast ion collective Thomson scattering (CTS) diagnostic results at TEXTOR, ASDEX Upgrade and status of ITER design , S.K. NIELSEN, Risoe-DTU/PSFC MIT, H. BINDSLEV, S.B. KORSHOLM, F. LEIPOLD, P. MICHELSEN, Risoe-DTU, P. WOSKOV, PSFC MIT, J.W. OOSTERBEEK, IPP-FZ Juelich, E. WESTERHOF, FOM, F. LEUTERER, D. WAGNER, IPP-Garching, TEXTOR TEAM, ASDEX TEAM — In ITER, fast alpha particles born in fusion processes will account for up to 70% of the heating power. Measurements of confined fast ions resolved in space, pitch angle, energy and time are needed to support improvements of current theories. Fast ion collective Thomson scattering (CTS) can meet this need. Here we present results from CTS on TEXTOR where a 150 KW 110GHz gyrotron scatters off fluctuations driven by NBI/ICRH fast ions. The 1D fast ion velocity distribution has been inferred, where the resolved direction and the measuring volume are defined by the scattering geometry. The spatial resolution is ~10 cm while the temporal resolution is 4 ms. The build-up and slowdown of co-injected neutral beams are reported along with comparisons between co and counter beam ion dynamics. The measured decay and build-up of co NBI is in agreement with classical slowing down. First results from ASDEX Upgrade, where a 105 GHz system is installed are expected to be presented. Finally, the status of the 60 GHz CTS diagnostic design proposed for ITER is presented. Supported by U. S. DoE and EURATOM.

CP8.00076 The motional Stark effect with laser-induced fluorescence diagnostic , ELIZABETH FOLEY, FRED LEVINTON, Nova Photonics, Inc. — Traditional motional Stark effect (MSE) diagnostics exploit the polarization properties of light generated from a neutral hydrogenic beam via collisionally-induced fluorescence (CIF). MSE uses this information to determine a spatially resolved profile of the magnetic field pitch angle in a magnetized plasma. The use of laser-induced fluorescence with MSE on a dedicated diagnostic neutral beam enables an MSE pitch angle measurement at fields as low as 0.001 T, which cannot be achieved by CIF systems. The LIF system also affords the option of very precisely measuring the magnetic field magnitude as well as direction. The MSE-LIF diagnostic is under development in our laboratory, where we have a diagnostic neutral beam system, a dye laser, and a helicon plasma source. This poster will present the latest results relating to MSE-LIF measurements in plasma, as well as an analysis of the relative utility of magnetic field magnitude vs pitch angle measurements for equilibrium reconstruction.

CP8.00077 Velocity Field Analysis for Edge Turbulence Imaging , B.T. BROWN, T. MUNSAT, Center for Integrated Plasma Studies, University of Colorado, C. HOLLAND, G. TYNAN, Dept. Mechanical and Aerospace Engineering, UCSD — Techniques for extracting time-resolved 2-D velocity maps have been developed for turbulence imaging diagnostics. A hybrid technique combining optical flow and local pattern matching has been implemented to overcome the individual limitations of each when used with data of limited temporal and/or spatial resolution. The codes have been validated for a variety of test patterns of convective flow, including highly sheared cases. Recent work includes detailed consideration of the velocity divergence in the 2-D plane, and its significance to the derived results. We present comparison and validation studies to various artificial datasets with known velocity profiles, including sets with significant curl.

CP8.00078 Density fluctuation measurements with the microwave imaging reflectometry on TPE-RX[1] , Z.B. SHI, Grad. Univ. Adv. Studies, Y. NAGAYAMA, S. YAMAGUCHI, NIFS, Y. HIRANO, S. KIYAMA, H. KOGUCHI, H. SAKAKITA, K. YAMBE, AIST — Electron density fluctuation in a large reversed-field pinch device TPE-RX has been investigated by using the microwave imaging reflectometry (MIR) system for the first time. This system illuminates the TPE-RX plasma with the 20 GHz microwave beam in O-mode and measures the reflection by a two dimensional detector array with spatial resolution of 4cm and temporal resolution of 1ms. Each detector signal has 3 components, such as the amplitude, the in-phase (I) and the quadrature (Q). The reflection surface motion is obtained from the rotation of the I-Q components of the MIR signals. Cross-spectral method is used for the analysis of the amplitude of the reflected wave. We investigate four different types of RFP plasma, such as the quasi-single-helicity (QSH) plasma, the pulsed poloidal current drive (PPCD) plasma, the sawtoothing high theta plasma and the NBI heated plasma. The fluctuations indicate that the plasma turbulence is dominated by the low frequency and long wavelength fluctuation components and the statistical dispersion relation shows the typical electron drift wave characteristics.

[1]This work is supported by NIFS with No. KEIN0021 and No. ULPP525.

CP8.00079 Two-dimensional Thomson Scattering Measurement Using Multiple Reflection and the Time-of-Flight of Laser Light on TS-4 , TAKASHI SUMIKAWA, SHINGO ITO, KOHEI YAMASHITA, EIICHIROU KAWAMORI, YASUSHI ONO, University of Tokyo, UNIVERSITY OF TOKYO TEAM — A two-dimensional Thomson scattering (2-D TS) measurement system is being constructed on TS-4 device with major/minor radii of 0.5m/0.3m and its main tasks of plasma merging and confinement of ST (Spherical Tokamak) plasma. This system is intended to measure T_e in the range of 20-200eV for $n_e \sim 10^{20}$m^3 with a spatial resolution of 160mm (four points) in the r-direction and 130 mm (three points) in the z- direction. The new ideas of our 2-D TS system are (1) to reflect YAG laser light multiple times by mirrors to cover the whole r-z plane of the ST plasma, and (2) to utilize the time delay of the scattered light along the laser beam in order to reduce the necessary number of spectrometers and detectors. In a preliminary experiment, Rayleigh scattering light from two measurement points and Raman scattering light from three measurement points were successfully measured by a single spectrometer as their time evolutions, suggesting that the basic principle of the 2-D TS system functions effectively. To prepare for the TS measurement, the gas pressure dependency of Rayleigh and Raman scattering lights were observed for absolute calibration of the system. The first result of our TS system will be presented.

CP8.00080 Electron Density Profile Measurements of a Field-Reversed Configuration Using an Optical Interferometer[1] , J.F. CAMACHO, NumerEx, E.L. RUDEN, AFRL — A laser interferometer system operating at 633 nm is being used to measure the electron density of field-reversed configurations (FRCs) produced by the magnetized target fusion (MTF) experiment at the Air Force Research Laboratory (AFRL). The design is a scaled-down version of an eight-chord system previously used to provide time-resolved information about the spatial distribution of electron density in a similar FRC experiment [E. L. Ruden *et al.*, *Rev. Sci. Instrum.* **77**, 103502 (2006)]. Here, a fanned array of laser beams probes the plasma through the FRC midplane along four different chords. In addition, our design features the option of diverting any or all of the four probe beams into single-mode optical fibers whose collimated outputs can be used to probe different axial locations simultaneously [L. M. Smith *et al.*, *Rev. Sci. Instrum.* **74**, 3324 (2003)]. This arrangement enables us to place the interferometer system's optical table at a safe distance from the MTF-FRC experiment when destructive tests involving plasma compression by a solid metal liner imploded by the Shiva Star capacitor bank are attempted. Data from the four-chord system and the system with the fiber-optic probe beam modification will be presented.

[1]Work supported by the DOE Office of Fusion Energy Sciences.

CP8.00081 Three dimensional full-wave simulations of reflectometry in toroidal plasma , ERNEST VALEO, GERRIT KRAMER, RAFFI NAZIKIAN, PPPL, Princeton, NJ — A three-dimensional wave propagation code, developed specifically to simulate correlation reflectometry in large scale fusion plasmas is described. The code extends an algorithm previously implemented in 2D [E. J. Valeo, G. J. Kramer, and R. Nazikian, Plasma Phys. Control. Fusison **44** (2002) L1-L10], in which separate computational methods in the vacuum, underdense and reflection regions of the plasma are implemented in order to obtain the high computational efficiency necessary for correlation analysis. Simulations of ITER plasma are presented which demonstrate the efficiency of the method.

CP8.00082 A Multi-Channel, Frequency Comb Doppler Reflectometry System[1] , J.C. HILLESHEIM, W.A. PEEBLES, T.L. RHODES, L. SCHMITZ, T.A. CARTER, UCLA — Enhanced diagnostic capabilities are needed for the study of turbulent transport, zonal flows, and global modes (TAE, NTM, etc.) in fusion plasmas. Doppler reflectometry is a microwave diagnostic technique that produces localized measurements of intermediate-scale ($k_\perp \rho_i \sim 1$) density fluctuations and turbulence flow. A microwave beam is launched at an angle with respect to normal to the cutoff layer; backscattering occurs for density fluctuations near the cutoff layer according to the Bragg condition. The incident angle can be varied to probe the k-spectrum of the turbulence and the Doppler shift of the return signal provides the poloidal velocity of the fluctuations. A comb generator will be used to create 8 distinct launch frequencies, separated by ~2 GHz, in the 34-50 GHz range. The receiver will consist of a local oscillator at 32 GHz and a high-frequency mixer. The down-converted output, ranging 2-18 GHz, will be amplified, power split, and frequency selected via filter bank. Amplitude and phase information will be obtained by using radio frequency quadrature mixers. Technical details and results from laboratory testing will be presented.

[1]Supported by the DOE-ORISE FES Fellowship Program and by the US DOE under DE-FG03-01ER54615.

CP8.00083 ECE Imaging Bandwidth Upgrade for TEXTOR[1] , C.W. DOMIER, P. ZHANG, N.C. LUHMANN, JR., University of California at Davis, H.K. PARK, Princeton Plasma Physics Laboratory, M.J. VAN DE POL, G.W. SPAKMAN, R. JASPERS, A.J.H. DONNE, FOM-Institute for Plasma Physics Rijnhuizen — The 128 channel 2-D Electron Cyclotron Emission (ECE) Imaging system collects time-resolved 16×8 images of electron temperature profiles and fluctuations on the TEXTOR tokamak. This instrument was upgraded in February 2007 with new wideband ECE electronics which increased the instantaneous frequency coverage by >50% to 6.4 GHz with a corresponding increase in horizontal plasma coverage. Frequency extenders have been developed to combine modules together to double the instantaneous coverage to 12.8 GHz. Technical details regarding both the electronics upgrade and the frequency extenders as well as the preliminary physics results will be presented. Implementation of a similar but new ECEI instrument on the DIII-D tokamak will be extensively discussed.

[1]Work supported by U.S. DoE Grants DE-FG02-99ER54531 and DE-AC02-76CHO307, and by NWO and the Association EURATOM-FOM.

CP8.00084 Development of free-standing diffractive optical elements as light extractors for burning plasma experiments , D. STUTMAN, G. CARAVELLI, M. FINKENTHAL, A. TOLEA, Johns Hopkins University, G. WRIGHT, University of Madison-Wisconsin, D. WHYTE, Massachusetts Institute of Technology, N. MOLDOVAN, Northwestern University — Optical diagnostics will be critical for the operation and performance assessment of burning plasma experiments, such as ITER. At the same time, extracting light for these diagnostics with reflective mirrors becomes difficult in the burning plasma environment, due to prolonged exposure to plasma and nuclear radiation. As an alternative, we explore free-standing diffractive optical elements, such as transmission gratings and zone plates. Since in the case of diffractive extractors the light is deflected by periodic slits rather than a surface, they may withstand plasma exposure with less degradation of their optical properties. To investigate this possibility we developed free-standing transmission gratings for the visible range and exposed them in to conditions resembling or exceeding those expected for the ITER 'first mirrors'. The results of this study indicate that the gratings can withstand high heat fluxes and plasma and energetic radiation bombardment. In addition, in contrast to the reflective elements, the extraction capabilities of the diffractive elements can also improve with plasma exposure, due for instance to shaping and thinning of the grating bars by plasma erosion. Work supported by US DoE grant DE-FG02-99ER54523.

CP8.00085 SIMULATION: ALGORITHM —

CP8.00086 Implementation of Language Interoperability Interfaces for NTCC transport models as part of FMCFM project[1] , SRINATH VADLAMANI, Tech-X Corporation, A.Y. PANKIN, Lehigh University, S. KRUGER, A. PLETZER, J. CARLSSON, J. CARY, Tech-X Corp. — A new generalized interface to the transport modules and libraries from the National Transport Code Collaboration (NTCC) module library [1] is presented. The interface is created as a part of the Framework for Modernization and Componentization of Fusion Modules (FMCFM) project. The interface utilizes the technologies of encapsulation and polymorphism available in Fortran-95 that replace the COMMON BLOCK approach typical for Fortran legacy codes and allows us to create a generalized interface to the reduced transport modules. The new interface facilitates access to the transport models from integrated modeling codes and allows interlanguage interfaces using a new library of C++/Fortran-95 wrappers. This library also includes a collection of subroutines for data access from C/C++ to the Fortran 90 derived data structures. The new interface to transport modules has been applied to the the GLF23 and MMM95 transport models. The functionality is demonstrated in Framework Application for Core-Edge Transport Simulations (FACETS) project.
[1] A. H. Kritz *et al.* Comp. Phys. Communications **164** (2004) 108.

[1]Work funded by OFES SBIR grant DE-FG02-05ER84383.

CP8.00087 Parallel, Implicit, Finite Element Solver , WESTON LOWRIE, URI SHUMLAK, ERIC MEIER, GEORGE MARKLIN, University of Washington, PLASMA SCIENCE AND INNOVATION CENTER (PSI CENTER) COLLABORATION — A parallel, implicit, finite element solver is described for solutions to the ideal MHD equations and the Pseudo-1D Euler equations. The solver uses the conservative flux source form of the equations. This helps simplify the discretization of the finite element method by keeping the specification of the physics separate. An implicit time advance is used to allow sufficiently large time steps. The Portable Extensible Toolkit for Scientific Computation (PETSc) is implemented for parallel matrix solvers and parallel data structures. Results for several test cases are described as well as accuracy of the method.

CP8.00088 New quasi-Newton solver for transport equations[1] , JOHAN CARLSSON, JOHN R. CARY, ALEX PLETZER, Tech-X Corporation — A new quasi-Newton algorithm has been developed for systems in which the Jacobian has a block structure, as is the case for finite-difference approximations of transport equations where the fluxes depend only on the local field values and their gradients. A primary goal of this work is to minimize the number of numerically expensive flux calculations (e.g. diffusivities). Secondary design considerations were 2^{nd} order temporal and spatial discretization error, good numerical stability, and a modular design. Like the most common quasi-Newton algorithm, the Broyden method, our new quasi-Newton approach, the Block Hyper-Secant (BHS) approximation, uses flux evaluations from previous Newton iterations to approximate the Jacobian. If the flux evaluations dominate the computation time, the approximate Jacobian is thus free. Unlike Broyden, the BHS approximation converges toward the finite-difference Jacobian after sufficiently many iterations. An implicit transport solver, 2^{nd} order in time and space, has been implemented using the BHS solver to calculate the field increments. Numerical studies will be presented of its spatial and temporal accuracy as well as stability for time steps exceeding the CFL limit by many orders of magnitude. The FACETS FSP project has started using the BHS solver for core transport simulations and preliminary results will be presented.

[1]Work funded by OFES SBIR grant DE-FG02-05ER84383

CP8.00089 Mathematical Properties of the Flowing MHD Equilibrium Equations[1] , M. MIAH, J. CARY, A. HAKIM, S. KRUGER, A. PLETZER, S. VADLAMANI, Tech-X Corporation — Experiments have observed significant toroidal and poloidal flows in their plasmas [1-3]. This has led to the need for a flowing equilibrium solver that is equipped to handle both fixed and free boundaries. In order to achieve this, the mathematical properties of the flow equilibrium equations need to be better understood. Difficulty arises when analyzing these equations since they are not only fully non-linear, but also the differential operator itself is coupled to an algebraic equation. We discuss the method and process used to formulate the equilibrium problem with flow effects in a computationally tractable form and the methods available to solve the resulting equations. Initial results from an implementation of the equilibrium equations are also presented.

[1] S.K. Erents, A.V. Chankin, G.F. Matthews, P.C. Stangeby, Plasma Phys. Controlled Fusion 42, 905 (2000).
[2] T.S. Taylor, H.St. John, A.D. Turnbull, et al. Plasma Phys. Controlled Fusion 36 B229 (1994).
[3] M. Ono, S.M. Kaye, Y.K.M. Peng et al. Nucl. Fusion 40, 557 (2000).

[1]Supported by DoE Grant DE-FG02-05ER84192.

CP8.00090 Mesoscopic Detailed Balance Representations of Nonlinear Physics[1] , JEFFREY YEPEZ, AFRL, Hanscom Field, GEORGE VAHALA, William & Mary, LINDA VAHALA, Old Dominion University — We emphasize the similarity between entropic Lattice Boltzmann (ELB) and quantum lattice gas representations of nonlinear physics. At each space-time grid point, the excited state of a qubit encodes the probability that a mesoparticle moves along a lattice link. All the particle-particle interactions can be mapped onto a local unitary collision operator which locally entangles all the quibts at that node. This quantum entanglement is then spread throughout the lattice by unitary streaming. In the classical limit, there exists a fundamental discrete entropy function, and the collision operator is restricted that the post-collision distributions lie on a constant entropy surface and leads to a detailed balance ELB algorithm. This has been exploited in the solution of Navier-Stokes and MHD turbulence with div B = 0. On the other hand, with just 2 qubits/lattice site one can recovery the 3D Nonlinear Schrodinger equation of nonlinear optics and the Gross-Pitaevskii equation of BEC states under an appropriate unitary sequence of collide-stream. In particular, we examine solitary wave solutions of the GP equation and vortex nucleation.

[1]work supported by AFOSR and DoE

CP8.00091 A new nonlinear collision method for a particle code , EISUNG YOON, RAVI SAMTANEY, Princeton Plasma Physics Laboratory, TING RAO, DAVID KEYES, Columbia University, C.S. CHANG, HAROLD WEITZNER, L. GREENGARD, New York University — A new nonlinear collision operation method for a particle code is presented, which does not use the Monte Carlo scheme. Particle information is gathered on a 2D velocity grid and the particle distribution function is obtained by a penalized spline operation which conserves mass, momentum, energy, and entropy. After performing the fully nonlinear Rosenbluth-McDonand-Judd Fokker-Planck operation using advanced mathematical methods, the collision information is sent back to the particles. The new collision operation can reduce the discrete particle noise while performing physical Coulomb collisions. It can also significantly reduce the required frequency of collision operations due to absence of the Monte Carlo noise. Comparison with a well-known binary collision method will be given. The conservation properties will be discussed.

CP8.00092 A step towards addressing the temporal multi-scale problem.[1] , JING-MEI QIU, ANDREW CHRISTLIEB, Michigan State University, ROBERT KRASNY, University of Michigan — Plasmas display multi-scale features in space and in time. While application of methods such as Adaptive Mesh Refinement have made progress with regards to resolving multi-scale features in space, the temporal multi-scale nature of a two species plasma remains a challenging problem. Spectral Differed Correction (SDC) is intended to address the temporal multi-scale problem. In this work we consider the application of SDC to a particle formulation of the Vlasov-Poisson system as a way of accelerating temporal convergence. In particular, we consider the two-stream instability, as particle trapping is known to be an issue for temporal acceleration methods.

[1]This work is supported by AFOSR under grant numbers FA9550-07-0144 and FA9550-07-01-0092

CP8.00093 Boundary Integral Corrected Particle In Cell[1] , CHRISTLIEB ANDREW, Michigan State University, CARTWRIGHT KEITH, AFRL/DEHE — Numerical heating is a serous problem in PIC modeling of cross field Diffusion. Recent work by the author has shown that for, electrostatic problems, the Boundary Integral Treecode (BIT) has far less numerical heating than traditional PIC and that numerical heating can be nearly eliminated if regularization is added to the BIT field solver. In this work we consider the application of BIT as a sub-cell method within each PIC cell, where the boundary conditions on BIT come from the fields computed on the PIC mesh. The goal is to minimize numerical heating in PIC while allowing for mesh spacing in PIC to be much greater than a Debye length. Our overall objective is to inherit the parallel capability of legacy PIC codes while providing high accuracy.

[1]This work is supported by AFOSR under grant numbers FA9550-07-0144 and FA9550-07-01-0092.

CP8.00094 PARSEK: a Parallel Software Package for Implicit Particle-in-Cell Simulations , STEFANO MARKIDIS, GIOVANNI LAPENTA, ENRICO CAMPOREALE — A C++ software package, called PARSEK, for Particle-in-Cell(PIC) plasma simulations on parallel computers is presented. PARSEK computational engine is based on the fully implicit solution of discretized three dimensional Maxwell's equations and particle equation of motion. The implicit method allows to describe effectively low-frequency plasma phenomena without paying the severe restrictions of explicit numerical schemes on simulation time steps and grid spacing. The fully implicit PIC method is now developed on parallel computer architecture. With implicit numerical schemes and parallel software architecture, PARSEK extends considerably time and space scale domains of PIC simulations. PARSEK software components, with emphasis on the development of the implicit PIC method on parallel computers, and a suite of applications, such as magnetic reconnection and relativistic streaming instabilities, are described.

CP8.00095 The EMPOWER Code: Electro-Magnetic Particle Operation With Enhanced Resolution , H. KARIMABADI, Y.A. OMELCHENKO, H.X. VU, SciberQuest, Inc/UCSD — Large-scale full PIC simulations play a crucial role in the modeling of laser-plasma interactions, accelerators, HPM devices and magnetic reconnection. These simulations ubiquitously employ uniform meshes, which severely limits their CPU speed and in many cases makes high-resolution runs prohibitive even on massively parallel computers. On the other hand, inadequate spatial resolution of realistic features (localized plasma volumes, device boundaries, etc.) is known to result in unacceptable errors. Structured adaptive mesh refinement (SAMR) has successfully been applied to fluid dynamics and MHD simulations. However, extending SAMR to practical electromagnetic particle-in-cell (PIC) models has proven to be nontrivial due to a number of additional numerical challenges, with spurious wave reflection and macro-particle self-force at the coarse-fine mesh interfaces being the most severe. These approximation errors typically result in a significant loss of simulation accuracy, energy/momentum non-conservation and long-time instabilities. We review our progress in resolving these issues in our new EM-PIC code, EMPOWER. We demonstrate the efficiency and accuracy of the new techniques on realistic examples related to simulations of high-power EM pulses and energetic particle beams.

CP8.00096 A New Simulation Algorithm Combining Fluid and Kinetic Properties[1] , DAVID LARSON, DENNIS HEWETT, LLNL — Complex Particle Kinetics (CPK) [1,2] uses particles with internal degrees of freedom in an effort to simulate the transition between continuum and kinetic dynamics. Recent work [3] has provided a new path towards extending the adaptive particle capabilities of CPK. The resulting algorithm bridges the gap between fluid and kinetic regimes. The method uses an ensemble of macro-particles with a Gaussian spatial profile and a Mawellian velocity distribution to represent particle distributions in phase space. In addition to the standard PIC quantities of location, drift velocity, mass, and charge, the macro-particles also carry width, thermal velocity, and an internal velocity. The particle shape, internal velocity, and drift velocity respond to internal and eternal forces. The particles can contract, expand, rotate, and pass through one another. The algorithm allows arbitrary collisionality and functions effectively in the collision-dominated limit. We will present details of the algorithm as well as the results from several simulations. [1] D. W. Hewett, *J. Comp. Phys.* **189** (2003). [2] D. J. Larson, *J. Comp. Phys.* **188** (2003). [3] C. Gauger, *et.al., SIAM J. Numer. Anal.* **37** (2000).

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

CP8.00097 Discrete-Event Simulation of Poisson-Based Particle Systems , Y.A. OMELCHENKO, H. KARIMABADI, SciberQuest, Inc/UCSD — We describe a new algorithm for simulating multi-scale kinetic (N-body) systems, where particles interact via potential forces obtained from the solution of Poisson's equation. Such models range from electrostatic plasma to fluid to astrophysical (gravitational) applications. Our technique is based on two novel principles: (i) we use a self-adaptive, *discrete-event simulation* (DES) technique [1,2] for the asynchronous integration of particle equations of motion; (ii) we find the particle forces by convolving mesh-averaged Green's functions with asynchronous *changes* to the particle (charge or mass) density, computed with respect to periodically updated reference states of the system. We demonstrate the new approach by providing examples of space-charge beam simulations. [1] H. Karimabadi, J. Driscoll, Y.A. Omelchenko, N. Omidi, J. Comp. Phys. 205, 755 (2005). [2] Y.A. Omelchenko, H. Karimabadi, J. Comp. Phys. 216, 153 (2006).

CP8.00098 A robust, efficient equidistribution 2D grid generation method , LUIS CHACON, GIAN LUCA DELZANNO, JOHN FINN, LANL, JEOJIN CHUNG, SMU, GIOVANNI LAPENTA, LANL — We present a new cell-area equidistribution method for two-dimensional grid adaptation [1]. The method is able to satisfy the equidistribution constraint to arbitrary precision while optimizing desired grid properties (such as isotropy and smoothness). The method is based on the minimization of the grid smoothness integral, constrained to producing a given positive-definite cell volume distribution. The procedure gives rise to a single, non-linear scalar equation with no free-parameters. We solve this equation numerically with the Newton-Krylov technique. The ellipticity property of the linearized scalar equation allows multigrid preconditioning techniques to be effectively used. We demonstrate a solution exists and is unique. Therefore, once the solution is found, the adapted grid cannot be folded due to the positivity of the constraint on the cell volumes. We present several challenging tests to show that our new method produces optimal grids in which the constraint is satisfied numerically to arbitrary precision. We also compare the new method to the deformation method [2] and show that our new method produces better quality grids. [1] G.L. Delzanno, L. Chacón, J.M. Finn, Y. Chung, G. Lapenta, *A new, robust equidistribution method for two-dimensional grid generation*, in preparation. [2] G. Liao and D. Anderson, A new approach to grid generation, Appl. Anal. 44, 285–297 (1992).

CP8.00099 A Mesh-Free Method for the Simulation of Magnetic Diffusion , JEFFREY JOHNSON, UC Davis / Lawrence Livermore National Lab, MICHAEL OWEN, Lawrence Livermore National Lab — Magnetohydrodynamics (MHD) plays an important role in various physical systems at large and small scales. Recently, mesh-free methods such as Smoothed Particle Magnetohydrodynamics [1] (SPMHD) have been developed to study these systems by simulating magnetic fields in the presence of conducting media. However, these methods currently do not incorporate realistic models for electrical resistivity, which can significantly affect the dynamics of the system by introducing magnetic diffusion, thereby altering the field's topology. We describe a Meshless Local Petrov Galerkin (MLPG) method that solves such magnetic diffusion problems using local weak forms composed of mesh-free shape functions. This MLPG method accommodates inhomogeneous and anisotropic electrical resistivity models and allows the magnetic field to be evolved implicitly in time. We have assembled several test problems of interest in order to verify the method. Ultimately, we aim to combine this MLPG method with a form of SPMHD in order to treat realistic resistive magnetohydrodynamic systems. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.
[1] D. J. Price, J. J. Monaghan, Mon. Not. Roy. Astr. Soc. Volume 348 Issue 1 pp. 123-138 (2004)

CP8.00100 Solution of the Boltzmann kinetic equation for arbitrary collisionality[1] , MARK L. ADAMS, HOWARD A. SCOTT, LLNL — Solving the nonlinear Boltzmann kinetic equation by traditional explicit numerical methods becomes increasingly difficult and costly as collisionality increases. However, many problems of scientific interest span the range from nearly collisionless to highly collisional regimes and remain beyond the reach of such methods. Thus, we develop an implicit solution technique to efficiently solve the Boltzmann equation for arbitrary collisionality. The technique builds upon methods developed for radiation transport and can be applied to a variety of numerical discretizations. As an example, we apply the method to a one-dimensional characteristic solution of the integral Boltzmann kinetic equation with Krook collision operator and a rigid elastic spherical atomic interaction potential. The technique can be extended to higher dimensions, applied to multiple atomic species, and is valid for more general interaction potentials. We present results for steady-state problems of Fourier flow and Couette flow over a large range of Knudsen numbers, and compare these with analytic results obtained using Chapman-Enskog theory.

[1]This work was performed under the auspices of the US Department of Energy by the University of California, Lawrence Livermore National Laboratory through contract W-7405-ENG-48.

CP8.00101 Regions of Validity for Common Plasma Models , R. LILLY, U. SHUMLAK, Aerospace and Energetics Research Program, University of Washington, Seattle, WA 98195-2600 — Common plasma models, consisting of the kinetic, two-fluid ten-moment, two-fluid five-moment, and MHD descriptions, are reviewed. The assumptions used in the derivation of the fluid models are discussed, in particular the limits of their validity. Specific assumptions about the collisionality with regard to the thermalization times are explored. Requirements for model closure will be examined, paying attention to the restrictions on the distribution function. How these assumptions are different between the two-fluid ten-moment, two-fluid five-moment and MHD models will also be examined. Dispersion relations for the resulting fluid descriptions will be derived, and the associated physics captured will be compared.

CP8.00102 SIMULATION: KINETIC/EDGE —

CP8.00103 Stability of the Long Wavelength Limit of ETG Modes , ERIC WANG, UCLA — The stability of long wavelength electron temperature modes is investigated ($k_\theta \rho_e \sim O(.1)$. The effects of kinetic ions as well as trapped electrons are included and discussed.

CP8.00104 Nonlinear finite-Larmor-radius effects in reduced fluid models[1] , A.J. BRIZARD, SMC, R.E. DENTON, W. LOTKO, Dartmouth — The polarization and magnetization effects associated with the process of dynamical reduction leading to nonlinear gyrokinetic theory [1] are shown to introduce nonlinear finite-Larmor-radius (NFLR) effects into nonlinear reduced-fluid equations [2]. These intrinsically nonlinear FLR effects, which are associated with the transformation from guiding-center phase-space dynamics to gyrocenter phase-space dynamics, are different from standard FLR corrections, which are associated with the transformation from particle phase-space dynamics to guiding-center phase-space dynamics. The reduced fluid equations with NFLR corrections are derived from a variational principle and, thus, automatically possess an exact energy conservation law. Simulation results show agreement with linear theory, nonlinear energy conservation, and mode coupling of Alfven and sound waves.
[1] A.J. Brizard and T.S. Hahm, Rev. Mod. Phys. **79**, 421 (2007).
[2] A.J. Brizard, Phys. Plasmas **12**, 092302 (2005).

[1]Work at SMC was supported by NSF grant DMS-0317339 and work at Dartmouth was supported by NASA grants NNG05GJ70G and NNG04GE22G and by NSF grants ATM-0632740 and ATM-0238694.

CP8.00105 Electrostatic turbulence on transport time scales[1] , PETER CATTO, MIT Plasma Science & Fusion Center, ANDREI SIMAKOV, Los Alamos National Lab, FELIX PARRA, GRIGORY KAGAN, MIT Plasma Science & Fusion Center, MIT PLASMA SCIENCE & FUSION CENTER COLLABORATION, LOS ALAMOS NATIONAL LAB COLLABORATION — Simulating electrostatic turbulence on transport time scales requires retaining a complete turbulence modified neoclassical (and classical) transport description, including all the axisymmetric radial neoclassical and zonal flow electric field effects, as well as the turbulent transport normally associated with drift instabilities. Neoclassical electric field effects are particularly difficult to retain since they require evaluating the ion distribution function to higher order in gyroradius over background scale length than standard gyrokinetic treatments. To avoid extending gyrokinetics an alternate hybrid gyrokinetic-fluid treatment is formulated that employs higher order moments of the full Fokker-Planck equation to remove the need for a higher order gyrokinetic distribution function. The resulting hybrid description is able to model all electrostatic turbulence effects with wavelengths much longer than an electron Larmor radius such as the ion temperature gradient (ITG) and trapped electron modes (TEM).

[1]Work supported by U.S. DoE.

CP8.00106 Development of a Grid-Based Gyrokinetic Simulation Code , STEPHAN BRUNNER, TRACH-MINH TRAN, XAVIER LAPILLONNE, MAURA BRUNNETTI, CRPP — A new grid-based code is being developed for solving the gyrokinetic equation in tokamak geometry. This development builds on the experience gained with the CYGNE project [M. Brunetti *et. al*, Comp. Phys. Comm. **163**, 1 (2004)], which solved the electrostatic drift-kinetic equations in a cylindrical system using a semi-Lagrangian approach. This new code makes use of efficient and flexible software modules optimized for parallel platforms. Preliminary results in reduced geometry, in particular slab and cylindrical, will be presented.

CP8.00107 A Low Moment Kinetic MHD Simulation Model[1] , SCOTT PARKER, JIANHUA CHENG, Univ. of Colorado — A wide variety of low-frequency macroscopic plasma phenomena are well described assuming quasi-neutrality, neglecting the displacement current and obtaining the electric field with a generalized Ohm's law. With this in mind, one can formulate the kinetic problem using ion density and ion flow moments. Kinetic electron physics enters via the electron pressure term in the generalized Ohm's law. Here, we formulate and test such a model with kinetic ions and an equation of state for the electrons. Whistler waves, shear Alfven waves (with finite gyro-radius corrections) and ion acoustic waves are present in the homogeneous plasma problem. Simulation results with this model are compared to the linear dispersion relation, including ion Landau damping. This simple kinetic particle model based on evaluating lower moments identically models the physics of more sophisticated extended-MHD models where ion kinetics closes via higher moments.

[1]Work supported by the SciDAC Center for Extended Magnetohydrodynamics.

CP8.00108 Discrete particle noise in gyrokinetic PIC simulations of plasma turbulence[1] , IGOR HOLOD, ZHIHONG LIN, University of California, Irvine — The studies of discrete particle noise have been done based on the gyrokinetic simulations of plasma turbulence using the gyrokinetic toroidal particle code (GTC). Statistical properties and associated transport of random fluctuations are first studied in a system with subcritical background gradients, such that no instabilities develop. Simulations in the parameter regime approaching marginality from below have subsequently been done, to study the effects of nonlinearity of the dielectric constant. The fluctuation spectra have been constructed from the direct simulation measurements of electrostatic potential. The noise- driven transport has been calculated using the quasilinear expression for the diffusivity. The obtained theoretical value for the diffusion coefficient is compared with the corresponding value obtained from the simulation, demonstrating good agreement. It has been shown that for the realistic parameters, the noise driven transport depends linearly on the entropy of the system, which, in particular, makes possible to estimate the noise contribution to the heat conductivity during simulations.

[1]This work was supported by U.S. DOE Cooperative Agreement No. DE-FC02-04ER54796, DOE Plasma Physics Junior Faculty Development Award, DE-FG02-03ER54724, NSF CAREER Award, ATM-0449606, and in part by the DOE SciDAC GPS Center

CP8.00109 Collisionless Heating in Gyrokinetic Turbulence[1] , WILLIAM DORLAND, University of Maryland — Heating in weakly collisional, turbulent plasma in the gyrokinetic regime (strong guide field, low frequencies compared to cyclotron frequencies, small perturbations, weak or strong turbulence) is usually associated with Landau and Barnes damping, which in turn are associated with parallel acceleration of particles by turbulent electric and magnetic fields. We discuss a novel form of heating observed in gyrokinetics which is distinct from these conventional processes. A simple theoretical framework is presented to explain the mechanism, which might be called "perpendicular phase mixing." The theoretical framework allows one to distinguish and separate two components of heating (acceleration and thermalization) and to identify different mechanisms for each. Numerical results are shown which support the theory.

[1]Supported by the Center for Multiscale Plasma Dynamics.

CP8.00110 Minimal models of finite Larmor radius effects on non-diffusive transport in two-dimensional plasmas[1] , KYLE GUSTAFSON, University of Maryland, DIEGO DEL CASTILLO NEGRETE, Oak Ridge National Laboratory, WILLIAM DORLAND, University of Maryland — In order to gain understanding of non-diffusive transport in a simplified regime, we investigate minimal but non-integrable models for chaotic advection based on the Hasegawa-Mima limit of the gyrokinetic equation[2]. These prescribed streamfunction models exhibit Lagrangian turbulence for passive tracer particles in the flow. In particular, particles execute Lévy flights as they drift between vortices and surrounding zonal flows. We give the ensemble of tracers a Maxwellian distribution of gyroradii, which allows us to report on finite Larmor radius (FLR) effects. Measurements of transport for an ensemble of such trajectories shows non-diffusive scaling of the variance, σ^2, such that $\sigma^2 \sim t^\alpha$, where $1 < \alpha < 2$. We show that the shape and the spatio-temporal scaling of the Lagrangian propagator can be modeled with fractional diffusion equations currently used to study non-local transport in plasmas. [3]. We find, as expected, that a larger average Larmor radius causes more particles to free-stream instead of travel in the stochastic layer. We also report on measures of the velocity correlations for passive particles in the flow, as this may be a useful technique for probing gyrokinetic turbulence.

[1]K. Gustafson is supported by the Fannie and John Hertz Foundation.

[2]del Castillo Negrete, Phys. Fluids 10, 1998

[3]del Castillo Negrete, Phys. Plasmas, 13 082308, 2006

CP8.00111 The role of conserved quantities in turbulence simulations , INGMAR BROEMSTRUP, WILLIAM DORLAND, MICHAEL BARNES, KYLE GUSTAFSON, University of Maryland — Direct numerical simulations of plasma turbulence have become an important tool for interpreting experimental data from tokamaks. There is, however, relatively little exploration of the fluctuation data that is produced by gyrokinetic simulations in the literature. In preparation for more detailed experimental validation of predictions from gyrokinetic simulations of plasma turbulence, we present studies of decaying turbulence and the influence of the conserved quantities to the cascading processes. Therefore we study first two simplified models: the Hasegawa-Mima model and a second model that allows for finite ion temperatures in the Hasegawa-Mima framework. Both models are studied using a spectral fluid code and a PIC code. The main focus is on how increasing the ratio of ion to electron temperature changes the cascading behavior. We will also discuss how the different simulation algorithms treat fine-scale velocity-space structure.

CP8.00112 Global gyrokinetic simulations using coupled flux-tubes[1] , MICHAEL BARNES, WILLIAM DORLAND, University of Maryland — A full treatment of the transport problem in modern fusion devices requires simultaneous resolution of rapidly-evolving, small-scale turbulence and slowly-evolving, large-scale variation of background profiles. The multiscale nature of the problem makes it computationally expensive. Consequently, relatively few high resolution global simulations exist. We extend the continuum gyrokinetic code GS2 to explore the use of coupled flux-tube simulations to simulate global plasma dynamics efficiently. Coupling between flux-tubes is achieved by solving the recently developed gyrokinetic transport equations of Wang, Plunk and Cowley. This allows us to obtain the self-consistent, steady-state, background profiles and corresponding turbulent fluxes. We present and discuss preliminary results.

[1]Work supported by the Center for Multiscale Plasma Dynamics

CP8.00113 Plasma Turbulence Simulation and Visualization on Graphics Processors: Efficient Parallel Computing on the Desktop , GEORGE STANTCHEV, DEREK JUBA, WILLIAM DORLAND, AMITABH VARSHNEY, University of Maryland — Direct numerical simulation (DNS) of turbulence is computationally very intensive and typically relies on some form of parallel processing. Spectral kernels used for spatial discretization are a common computational bottleneck on distributed memory architectures. One way to increase the efficiency of DNS algorithms is to parallelize spectral kernels using tightly-coupled SPMD multiprocessor hardware architecture with minimal inter-processor communication latency. In this poster we present techniques to take advantage of the recent programmable interfaces for modern Graphics Processing Units (GPUs) to carefully map DNS computations to GPU architectures that are characterized by a very high memory bandwidth and hundreds of SPMD processors. We compare and contrast the performance of our parallel algorithm on a modern GPU versus a CPU implementation of several turbulence simulation codes. We also demonstrate a prototype of a scalable computational steering framework based on turbulence simulation and visualization coupling on the GPU.

CP8.00114 Electrostatic kinetic turbulent cascade of entropy in magnetized plasmas[1] , T. TATSUNO, W. DORLAND, U Maryland, A.A. SCHEKOCHIHIN, Imperial, S.C. COWLEY, UCLA — Upon the outstanding agreement of Goldreich & Sridhar theory on astrophysical MHD turbulence with the assumption of anisotropy and critical balance [1], one may construct a gyrokinetic turbulent theory to explore the microscale behavior below the ion gyroscale [2]. In the global regime, it is shown that the fluctuations corresponding to Alfvén dynamics cascade independently from other fluctuations and that they don't exchange energy with one another as far as reduced MHD ordering holds. Applying the similar ordering to kinetic regime, we are led to gyrokinetic equations, which again support the cascades of kinetic Alfvén and compressive fluctuations without energy exchange. Thus we may conjecture that each fluctuation component exchanges energy at the ion gyroscale due to the strong coupling and start to cascade without energy exchange again below. Performing electrostatic decaying turbulence simulations with Boltzmann electrons using the gyrokinetic code `AstroGK`, we here show the first computational results of the one component, entropy cascade in the absence of kinetic Alfvén fluctuations, below the ion gyroscale. The preliminary calculation shows that the turbulent spectra agree very well with the predicted theory. [1] P. Goldreich & S. Sridhar, Astrophys. J. **438**, 763 (1995). [2] A. A. Schekochihin *et al.*, submitted to Astrophys. J.

[1]This work supported in part by the CMPD, DOE grant DEFC0204ER54784.

CP8.00115 Excitation of geodesic acoustic modes by drift waves and ion temperature gradient modes[1] , PARVEZ GUZDAR, IREAP, University of Maryland, College Park MD, USA, NIKHIL CHARABARTI, Saha Institute of Nuclear Research, Kolkata, India, RAGHVENDRA SINGH, PREDHIMAN KAW, IPR, Gandhinagar, India — We will present mode-coupling analysis for the nonlinear excitation of the geodesic acoustic modes (GAMs) in tokamak plasmas by drift waves as well as toroidal ion temperature gradient (ITG) modes. Both this studies indicate that a coherent three-wave interaction is the primary process by which GAMs can be excited. Furthermore the frequency matching condition provides a prediction of the characteristic radial scale-length of GAMs which is in reasonable agreement with observations and simulations. The study also indicates why GAMs are preferentially excited in the edge region of toroidal magnetic confinement devices.

[1]Work supported in part by DOE.

CP8.00116 Transport and the neoclassical tearing mode: Slab geometry , PAVEL POPOVICH, SIMON ALLFREY, STEVEN COWLEY, CMPD, UCLA — Due to very long discharges in ITER, NTMs can potentially grow to large widths, increasing transport and significantly degrading confinement. Understanding the processes of the island growth and their impact on the transport is thus of crucial importance. We are presenting a model of the NTM based on an expansion of the Fokker-Planck equation. As a first step, we will consider the islands in a curvature-free slab geometry (see also [1]). We are interested in the islands of the size such that the parallel transport around the island along the magnetic field lines happens on the same time scale as the radial transport across the island, $\chi_\parallel/l_\parallel^2 \sim \chi_\perp/w^2$. Assuming classical diffusion along the field lines and gyro-Bohm-like transport in the perpendicular direction, we obtain the scaling for the island width as $w \sim \sqrt{\rho_i L}$, which is the minimum island width for bootstrap drive (due to profile flattening). Using $\rho^{*1/2}$ as the expansion parameter, solution of the Fokker-Planck equation yields 2-D equations for the evolution of the electron and ion distribution functions. These equations are solved subject to boundary conditions provided by matching to an external MHD solution.
[1] S.J. Allfrey, P. Popovich and S.C. Cowley, 'The Neoclassical tearing mode: An anomalous transport process' (this conference).

CP8.00117 Hybrid Simulation of Ion Acoustic Waves Including Coulomb Collisions[1] , BRUCE COHEN, ANDRIS DIMITS, Lawrence Livermore National Lab., RUSSEL CAFLISCH, C.M. WANG, YANGHONG HUANG, UCLA Math Department, GIACOMO DIMARCO, Univ. of Ferrarra — Kinetic simulation of collective phenomena including Coulomb collisions in inhomogeneous plasma presents significant multi-scale challenges. When the ratio of the collisional-mean-free-path of an ion or electron species to the local scale length of the plasma properties or the electromagnetic fields varies from very much greater than unity (kinetic limit) to very much smaller than unity (fluid limit) over a domain of interest, comprehensive simulation becomes difficult; and a brute-force, first-principles approach is typically impractical because of the severe computational stiffness of the underlying physics. This paper reports progress on the development of a kinetic-fluid hybrid technique for plasma simulation intended to address such multiple scale situations. A specific application to the simulation of ion acoustic waves including both Landau damping and Fokker-Planck Coulomb collisions is presented.

[1]Work performed under the auspices of the U.S. Department of Energy, Office of Science, OASCR under contract W-7405-ENG-48 at LLNL and under grant DE-FG02-05ER25710 at UCLA.

CP8.00118 A Hybrid Monte Carlo Method for Coulomb Collisions[1] , RUSSEL CAFLISCH, UCLA, BRUCE COHEN, LLNL, GIACOMO DIMARCO, U. Ferrara , ANDRIS DIMITS, LLNL, YANGHONG HUANG, RICHARD WANG, UCLA — This presentation describes a hybrid computational method for Coulomb collisions in a plasma that combines a Monte Carlo particle simulation and a fluid dynamic solver in a single uniform method throughout phase space. The new method is based on a hybrid representation of the velocity distribution function $f(v)$, as a combination of a Maxwellian equilibrium $M(v)$ and a collection of discrete particles $g(v)$. The Maxwellian M evolves in space and time through fluid-like equations, and the particles in g convect and collide through Nanbu's Monte Carlo particle method (PRE 1997). Interactions between M and g are represented by a thermalization process that removes particles from g and includes them in M and a dethermalization process that samples particles from M and inserts them into g. As test cases for the hybrid method, we have used relaxation of an anisotropic Maxwellian and evolution of a bump-on-tail.

[1]Work performed for USDOE by Univ. California LLNL under contract W-7405-ENG-48 and by UCLA under grant DE-FG02-05ER25710.

CP8.00119 Simulation of sheath problems with an accelerated Monte Carlo method[1] , YANGHONG HUANG, RUSSEL CAFLISCH, University of California, Los Angeles, BRUCE COHEN, Lawrence Livermore National Laboratory, GIACOMO DIMARCO, University of Ferrarra, Italy, ANDRIS DIMITS, Lawrence Livermore National Laboratory, CHIAMING WANG, University of California, Los Angeles — We simulate the interactions between a plasma and an absorbing wall in a confined volume with an accelerated Monte Carlo method for Coulomb Collisions. We treat ions as particles and the electrons to be continuum. Our method is based on the earlier work developed in the context of rarefied gas dynamics by Pareschi and Caflisch (J. Comp. Phys, 1999) and the Coulomb collision model developed by Nanbu (PRE 1997). The hybrid formulation combines particle and continuum methods and uses a thermalization and dethermalization procedure to accelerate the computation while retaining accuracy of the solution. We investigate sheath formation and compare the simulation results between Nanbu's particle method and the hybrid method.

[1]Work performed for USDOE by Univ. California LLNL under contract W-7405-ENG-48 and by UCLA under grant DE-FG02-05ER25710.

CP8.00120 The neoclassical tearing mode: An anomalous transport process , SIMON ALLFREY, PAVEL POPOVICH, STEVEN COWLEY, CMPD, UCLA — The Neoclassical tearing mode (NTM) is one of the key determinants of tokamak plasma transport. The understanding of stability and transport effects in tokamak plasmas is of crucial importance for the design of fusion devices like ITER. A fully consistent island evolution model should include turbulent (anomalous) transport for the correct calculation of *e.g.* radial fluxes and anomalous viscosity (which determines island rotation and hence the stabilizing or destabilizing role of the polarization current). As a first step and a "proxy" for turbulent transport, we use a neoclassical model. A neoclassical description allows us to develop a closed model that both consistently includes transport effects on the island growth and provides the appropriate basis for the inclusion of micro-turbulent transport (see [1]). The 'true' (anomalous) fluxes can be obtained from a flux-tube turbulence code. The separation of scales (turbulence smaller than the island) and times (turbulent transport faster than the island evolution) allows us to consider the island as a large (relative to the turbulence length scale) and slowly evolving structure for which local flux-tube calculations of transport is appropriate.
[1] P. Popovich, S.J. Allfrey and S.C. Cowley, 'Transport and the neoclassical tearing mode: Slab geometry' (this conference).

CP8.00121 Tempest simulations of kinetic GAM mode and neoclassical turbulence[1] , X.Q. XU, A.M. DIMITS, LLNL, ESL TEAM — TEMPEST is a nonlinear five dimensional (3d2v) gyrokinetic continuum code for studies of H-mode edge plasma neoclassical transport and turbulence in real divertor geometry. The 4D TEMPEST code correctly produces frequency, collisionless damping of GAM and zonal flow with fully nonlinear Boltzmann electrons in homogeneous plasmas. For large q=4 to 9, the Tempest simulations show that a series of resonance at higher harmonics $v_{||} = \omega_G qR_0/n$ with n=4 become effective. The TEMPEST simulation also shows that GAM exists in edge plasma pedestal for steep density and temperature gradients, and an initial GAM relaxes to the standard neoclassical residual with neoclassical transport, rather than Rosenbluth-Hinton residual due to the presence of ion-ion collisions. The enhanced GAM damping explains experimental BES measurements on the edge q scaling of the GAM amplitude. Our 5D gyrokinetic code is built on 4D Tempest neoclassical code with extension to a fifth dimension in toroidal direction and with 3D domain decompositions. Progress on performing 5D neoclassical turbulence simulations will be reported.

[1]Work performed for U.S. DOE by U.C. LLNL under Contract W7405-ENG-48.

CP8.00122 Toward an implicit Drift-Lorentz mover[1] , R.H. COHEN, A. FRIEDMAN, D.P. GROTE, LLNL, J.-L. VAY, LBNL — In order to efficiently perform particle simulations in systems with widely varying magnetization, we have developed a "drift-Lorentz mover," which interpolates between full particle dynamics and drift kinetics in such a way as to preserve a physically correct gyroradius and particle drifts for both large and small ratios of the timestep to the cyclotron period[2]. We are now adding implicitness to the mover and the associated field solver in order to extend the mover's applicability to systems with plasma frequency exceeding the cyclotron frequency. A first step was adding the polarization charge to the field solver and a two-time-level predictor corrector procedure [3]. We outline here two approaches to adding further implicitness. In both, we add a direct-implicit algorithm to the Lorentz portion of the mover; the drift portion can then be treated as in Ref. 3, or fully implicitly, with a modified predictor-corrector procedure. We describe the algorithms, stability analyses, and status of implementation.

[1]Work performed for the U.S. Department of Energy by U.C. LLNL and U.C. LBNL under contracts W7405-ENG-48 and DE-AC02-05CH11231.
[2]R.H. Cohen, A. Friedman, M. Kireeff Covo, et. al., Phys. Plasmas **12**, 056708 (2005).
[3]R.H. Cohen, A. Friedman, D.P. Grote and J.-L. Vay, Nucl. Inst. Methods A 577, 52 (2007).

CP8.00123 Gyrokinetic Models for Edge Plasmas[1] , A.M. DIMITS, R.H. COHEN, X.Q. XU, LLNL, AND THE ESL TEAM — We summarize a gyrokinetic model for charged-particle species in MFE edge plasmas and address several important issues. 1) The gyrokinetic Vlasov equations should be in conservation form to facilitate a conservative discretization. 2) The differences between the orderings used and results obtained by Qin et. al. [electromagnetic, and targeted to edge plasmas; Phys. Plasmas 14, 056110 (2007)] and Hahm et al. [electrostatic and targeted to core transport barriers; Phys. Plasmas 3, 4658 (1996)] are examined. Both assume that the electric potential is split into a large long-wavelength part and a small-amplitude perturbed part. Qin asserts that his particular form of the second-order potential is needed for energy conservation. 3) We examine practical forms of the gyrokinetic Poisson-Maxwell equations for the case when the perturbations are neither small-amplitude nor long-wavelength. 4) We build on the theoretical formulations of large-amplitude Gyrokinetic Coulomb collision operators (when linearization does not apply; e.g., by Brizard and by Qin et. al.) to develop an operator suitable for numerical implementation.

[1]Work performed for U.S. DOE by U.C. LLNL under Contract W7405-ENG-48.

CP8.00124 Particle-in-cell modelling of plasma deposition in castellated divertor targets , RADOMIR PANEK, MICHAEL KOMM, RENAUD DEJARNAC, Institute of Plasma Physics AS CR, v.v.i., Association EURATOM/IPP.CR, Prague, Czech Republic, JAMES GUNN, Association EURATOM/CEA, CEA/DSM/DRFC, Centre de Cadarache, France — JET and ITER plasma facing components (PFC) are segmented into cells to minimise the mechanical stress that is produced by thermal expansion of the components under plasma/radiative loads. This complex geometry introduces a significant complication in the estimation of the power load of these components, as the gap width can be comparable to the ion Larmor radius. We present results of two-dimensional, self-consistent kinetic simulations of this problem using the SPICE2 code based on a particle-in-cell technique. It has been developed for edge plasma simulations using arbitrary velocity distribution functions. The code is highly optimized and is designed for computationally demanding simulations. The code follows the charged particle trajectories on their way to the PFCs and estimates the plasma deposition in a non-symmetric electric potential. The results of power and particle loads calculations are presented for JET and ITER conditions.

CP8.00125 Simulations of dimensionless parameter experiments using theory-based transport models[1] , L. LABORDE, D. MCDONALD, I. VOITSEKHOVITCH , EURATOM-UKAEA, JET EFDA COLLABORATION — Dimensionless plasma parameter analyses are widely recognized as powerful tools for the study of energy and particle confinement, and also provide key quantities for the estimation of performance in future thermonuclear devices. Here we describe transport modelling of dimensionless parameter experiments using the theory-based models GLF23 and MMM95. Firstly, the β and ν* dependence of heat transport in the models is determined by running them stand-alone with imposed plasma profiles. In the JET parametric domain used in recent dedicated β scan experiments, MMM95 predicts a β degradation of confinement caused by the ideal MHD ballooning mode, whereas GLF23, which has a critical β value higher than the experimental β range, predicts a weak dependence. Secondly, the models are used in ASTRA predictive simulations of Ti and Te in order to test the capability of the models to reproduce experimental results. Despite a reasonable agreement with experimental profiles, the models sensitivity to the dimensionless parameters mismatch throughout the scan may lead to a wrong interpretation of the results. This is checked by running predictive simulations using modified input parameters in order to correct the mismatch.

[1]Work supported by Euratom and UK EPSRC.

CP8.00126 Effect of fast-ion loss on momentum transport in tokamak plasmas with toroidal field ripples , MITSURU HONDA, TOMONORI TAKIZUKA, Japan Atomic Energy Agency, ATSUSHI FUKUYAMA, Kyoto University, MAIKO YOSHIDA, TAKAHISA OZEKI, Japan Atomic Energy Agency — One-dimensional transport code, TASK/TX, has been developed to study the plasma rotation and the radial electric field in tokamak plasmas [1]. The code simultaneously solves a set of the two-fluid equations in the quasi-toroidal coordinates coupled with Maxwell's equations and beam-ion slowing down equation. It is observed in JT-60U that the reduction of the toroidal field ripple by installing ferritic steel tiles tends to rotate the plasma in the co direction because the counter rotation caused by the fast-ion loss is suppressed [2]. A model of the ripple loss has been made to study the phenomena and the behavior of the beam ions affected by the ripples can be self-consistently calculated. Numerical solutions reproduce the reduction of the toroidal co-rotation with co and perpendicular NBIs as the ripple amplitude increases. The toroidal rotation varies with the ripple amplitude at constant pressure gradient, as is observed in JT-60U [2], and the radial electric field also changes near the peripheral. This implies the change of the toroidal rotation strongly relates to that of the radial electric field through the radial force balance.
[1] M. Honda and A. Fukuyama, submitted to J. Comput. Phys.
[2] M. Yoshida, et al., Plasma Phys. Control. Fusion **48** 1673 (2006).

CP8.00127 Charging and Rotation of Pellet Ablation Cloud[1] , ROMAN SAMULYAK, TIANSHI LU, Brookhaven National Laboratory, PAUL PARKS, General Atomics — The interior of pellet ablation clouds charge to a negative electric floating potential because the incident plasma ions are stopped in a thin layer at the cloud/plasma interface, and this floating potential varies radially causing $E \times B$ rotation of the cloud with azimuthal velocities of order $v_\theta \simeq T_e/Br_c$ [1]. Numerical simulations of this effect with a time-dependent pellet ablation model have been performed using the front tracking based MHD code. The main features of the model include a self-consistent evolving potential distribution in the ablation cloud, inward $J \times B$ forces and outward centrifugal forces, atomic processes, and an improved electrical conductivity model which accounts for direct impact ionization of the cold ablated neutrals by the incident plasma electrons. The major conclusion of the study is that the cloud rotation reaches velocities comparable to ablation sound speeds, and therefore the centrifugal force adds significantly to the pressure gradient forces, thus broadening the width of the field aligned ablation channel. Cloud widening, in turn, reduces the cloud opacity and leads to a 30% increase in the ablation rate compared to the no rotation case for pellets crossing the pedestal region in ITER.
[1] P.B. Parks, Plasma Phys. Control. Fusion 38, (1996) 571.

[1]Supported by the U.S. DoE under Contract No. DE-AC02-98CH10886.

Monday, November 12, 2007 3:00PM - 5:00PM –

Session DI2 Reconnection, Gamma-Ray Bursts, and Angular Momentum Transport Rosen Centre Hotel Salon 3/4

3:00PM DI2.00001 Towards a New Understanding of Collisionless Magnetic Reconnection , WILLIAM DAUGHTON, Los Alamos National Laboratory — A central cornerstone of modern concepts regarding fast magnetic reconnection has been the expectation that the non-ideal electron region remains localized on the electron scale. Based on this understanding, it has been widely argued that the reconnection rate is controlled by the ions in a manner that is insensitive to the specific details of the electron physics. This picture implies that a single x-line will lead to steady reconnection with an open geometry similar to the Petscheck model. These expectations were largely based on two-fluid simulations and small-scale kinetic simulations with periodic boundary conditions. Recently, this problem was re-examined using 2D fully kinetic simulations with open boundary conditions [1] as well as the largest periodic simulations ever considered. In contrast to previous expectations, both of these approaches demonstrate that the length of the electron diffusion region expands in time to form a highly elongated current layer with a width on the electron scale but a length that can exceed tens of ion inertial lengths. These non-ideal electron layers exhibit multiple scales in the outflow direction[2] with an inner region characterized by strong out-of-plane current and an outer region marked by a collimated electron jet. The formation of these highly elongated layers involves a competition between the outward convection of magnetic flux with the non-ideal terms arising from the divergence of the electron pressure tensor. Although it is possible to setup a balance over limited durations, the resulting layers are always highly elongated. Over longer time scales, these layers are unstable to the formation of secondary magnetic islands leading to a reconnection process that is inherently time-dependent. These results point to a very different picture regarding the essential physics of reconnection since both the reconnection rate and time dependence are sensitive to the details of the electron physics.

[1]Daughton, Scudder and Karimabadi, *Phys. Plasmas* **13**, 072101,2006

[2]Karimabadi, Daughton and Scudder, *Geophys. Res. Lett.* **34**, L13104, 2007

3:30PM DI2.00002 Three-dimensional magnetic reconnection in Earth's magnetosphere , JOHN DORELLI, Space Science Center, University of New Hampshire — Magnetic reconnection is thought to be the primary mode by which the solar wind couples to the terrestrial magnetosphere, driving phenomena such as magnetic storms and aurorae. While the theory of two-dimensional reconnection is well developed, and has been applied with great success to axisymmetric and toroidal systems such as laboratory plasma experiments and fusion devices, it is difficult to justify the application of two-dimensional theory to nontoroidal plasma systems such as Earth's magnetosphere. Unfortunately, the theory of three-dimensional magnetic reconnection is much less well developed, and even defining magnetic reconnection has turned out to be problematic. In this talk, we review recent progress in the use of MHD to address the physics of three-dimensional reconnection in Earth's magnetosphere. The talk consists of two parts. In the first part, we review the various definitions of three-dimensional reconnection which have appeared in the literature in the last twenty years. Our goal here is to map these definitions to sets of physical phenomena which have been identified as "reconnection" in various three-dimensional contexts. In the second part of the talk, we present our latest magnetosphere MHD simulation results and indentify two qualitatively distinct types of reconnection phenomena (organized by the orientation of the Interplanetary Magnetic Field): 1) steady separator reconnection under generic northward IMF conditions, involving plasma flow across magnetic separatrix boundaries, and 2) time-dependent reconnection under generic southward IMF conditions, involving a global change in the topology of the magnetic field. While neither of these types of reconnection is well described by two-dimensional theory (indeed, we argue that attempts to apply two-dimensional ideas to the magnetopause have resulted in more confusion than clarification), both can be easily categorized according to existing definitions of three-dimensional reconnection.

4:00PM DI2.00003 Jitter radiation mechanism — a diagnostic tool of Weibel turbulence and Gamma-Ray Bursts[1] , MIKHAIL MEDVEDEV, University of Kansas — The Weibel instability is common in laser-produced plasmas and, as one has recently realized, it plays a major role in the formation and dynamics of astrophysical shocks of gamma-ray bursts (GRBs) and, perhaps, supernovae. Thanks to technological advances in the recent years, experimental studies of the Weibel instability are now possible at Petawatt- scale laser plasma facilities (such as NIF, Omega, etc) and in direct particle-in-cell (PIC) numerical simulations. We, thus, have a unique opportunity to model and study astrophysical conditions in numerical and laboratory experiments. At this stage, accurate diagnostic techniques are of great demand. In this presentation, we will discuss the physics of radiation, referred to as the *Jitter Radiation*, emitted by relativistic electrons (e.g., an electron beam or a thermal distribution) moving through the Weibel-generated magnetic fields, to which we refer as the *Weibel turbulence*. The similarity of Jitter radiation and the newly introduced "diffusive synchrotron radiation" is stressed. We'll show that the Jitter radiation field is anisotropic with respect to the direction of the Weibel current filaments and that its spectral and polarization characteristics are determined by microphysical plasma parameters. With the present computing capabilities, it is feasible to obtain radiation from plasma with Weibel-generated fields directly from PIC simulations, for the conditions relevant to laboratory laser- plasma experiments and relativistic astrophysical shocks of GRBs. Synergy of computer modeling, laboratory experiments and astrophysical observations will provide unique possibilities to diagnose plasma conditions in wide range of systems, thus putting *Plasma High-Energy Astrophysics* on the firm quantitative basis.

[1]Supported by DoE grants DE-FG02-04ER54790 and DE-FG02-07ER54940 and by NASA grant NNX07AJ50G.

4:30PM DI2.00004 Experimental Study of Angular Momentum Transport in Astrophysically Relevant Flows[1] , HANTAO JI[2], Center for Magnetic Self-organization, Princeton Plasma Physics Laboratory, Princeton University — Rapid angular momentum transport in accretion disks is a longstanding astrophysical puzzle. Transport by molecular viscosity is inadequate to explain observationally inferred accretion rates. Since Keplerian flows are linearly stable in hydrodynamics, there exist only two main viable mechanisms for the required turbulence: nonlinear hydrodynamic instability or linear magnetorotational instability (MRI). The latter is regarded as a dominant mechanism for rapid angular momentum transport in hot accretion disks ranging from quasars and X-ray binaries to cataclysmic variables. The former is proposed mainly for cooler protoplanetary disks, whose Reynolds numbers are typically large. Despite their popularity, however, there is limited experimental evidence for either mechanism. In this talk, I will describe a laboratory experiment at Princeton in a short Taylor-Couette flow geometry intended to study these mechanisms. Based on the results from prototype experiments and simulations, the apparatus contains novel features for better controls of the boundary-driven secondary flows. The experiments in water have shown[3] that nonmagnetic quasi-Keplerian flows at Reynolds numbers as large as 2×10^6 are essentially laminar, through means of direct measurements of Reynolds stress via a synchronized, dual Laser Doppler Velocimetry. Scaled to accretion disks, rates of angular momentum transport lie far below astrophysical requirements. By ruling out hydrodynamic turbulence, our results indirectly support MRI as the likely cause of turbulence even in cool disks. The experiments in liquid gallium eutectic alloy have recently begun, and initial results on MRI as well as other related phenomena including numerical predictions will be also discussed if available.

[1]This work is supported by DOE, NASA and NSF.

[2]In collaboration with E. Schartman, M. Nornberg, M. Burin, J. Goodman, and W. Liu.

[3]H. Ji, M. Burin, E. Schartman, & J. Goodman, Nature **444**, 343-346 (2006).

Tuesday, November 13, 2007 8:00AM - 9:00AM –

Session FR1 Review: Direct-Drive Inertial Confinement Rosen Centre Hotel Junior Ballroom

8:00AM FR1.00001 Direct-Drive Inertial Confinement Fusion Implosion Physics[1] , R.L. MCCRORY, Laboratory for Laser Energetics, U. of Rochester — The direct-drive approach to inertial confinement fusion ignition and high gain will be reviewed, including results from recent experiments on the OMEGA Laser System, a general theory of target design and implosion hydrodynamics, and a discussion of future directions. Target design theory leads to optimized designs for conventional isobaric ignition [including polar direct drive (PDD)] and fast ignition. PDD is a concept that allows direct-drive ignition experiments, while the National Ignition Facility (NIF) is configured for indirect drive. The target design review will include the theory of adiabat shaping to suppress the Rayleigh–Taylor instability, hydrodynamic scaling from current to ignition-size implosions, and the latest ignition designs for conventional and fast-ignition targets. The Lawson criterion for ICF is presented in a form that can be experimentally determined. The experimental review will cover linear and nonlinear, single and multimode ablative Rayleigh–Taylor instability experiments; adiabat shaping; and low-velocity, low-adiabat implosions to achieve high areal densities for fast-ignition fuel assembly, shock ignition, PDD, and cryogenic implosion experiments. This intense activity has culminated in OMEGA experiments producing the highest compression (i.e., highest value of the areal densities) ever achieved in cryogenic implosions. Results from the OMEGA implosion campaigns provide an important physics validation for the nation's direct- and indirect-drive-ignition campaigns and increasing confidence that direct-drive ignition will be achieved on the NIF.

[1]This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

Tuesday, November 13, 2007 9:30AM - 12:30PM –

Session GI1 Direct Drive Inertial Confinement Fusion and Z Pinches Rosen Centre Hotel Junior Ballroom

9:30AM GI1.00001 Performance of Direct-Drive Cryogenic Targets on OMEGA , V.N. GONCHAROV, Laboratory for Laser Energetics, U. of Rochester — Cryogenic D_2 and DT targets are routinely imploded on the OMEGA Laser System to study ignition-relevant, high-convergence-ratio, direct-drive physics. High-performance target designs depend crucially on the accuracy of the physics models used to simulate the implosions. To validate the predictive capabilities of the physics models, computer simulations have been benchmarked against a variety of precision measurements, including laser-energy absorption, x-ray emission spectra, neutron and charged-particle yields and spectra, core emission spectra, and time-resolved hard-x-ray spectra (>20 keV). The target designs are characterized by the shell adiabat α (ratio of the fuel pressure to the Fermi-degenerate pressure) and the peak drive intensity. Targets for the OMEGA experiments included both "ice–CD" designs, consisting of a 65- to 100-μm ice layer with a 3- to 13-μm CD overcoat, and 40- to 70-μm wetted-foam designs with a 2- to 5-μm CH overcoat. The cryogenic shells were driven using high-contrast-ratio (up to 100) pulse shapes, including picket pulses to shape the adiabat inside the shell to improve stability. This talk will review the results of OMEGA cryogenic implosions with shell adiabats in the range $1 < \alpha < 10$ and peak intensities varying from 2×10^{14} to 1.5×10^{15} W/cm^2. High-areal-density, cryogenic fuel assembly ($\rho R >$ 0.2 g/cm^2,$\rho_{D2} \sim 100$ g/cm^3, 500 × LD) is achieved when the excessive hot-electron and radiation preheat is mitigated. The experimental database of cryogenic targets imploded on the OMEGA laser will be used to design direct-drive-ignition targets for the National Ignition Facility. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.
Contributors: R.S. Craxton, J.A. Delettrez, D.H. Edgell, R. Epstein, V. Yu. Glebov, D.R. Harding, S.X. Hu, I.V. Igumenshchev, R. Janezic, R.L. Keck, J.P. Knauer, S.J. Loucks, L.D. Lund, J.R. Marciante, J.A. Marozas, F.J. Marshall, D.N. Maywar, R.L. McCrory, P.W. McKenty, D.D. Meyerhofer, P.B. Radha, S.P. Regan, R.G. Roides, T.C. Sangster, W. Seka, V.A. Smalyuk, J.M. Soures, C. Stoeckl, and S. Skupsky, *UR/LLE*; J.A. Frenje, C.K. Li, R.D. Petrasso, *MIT-PSFC*; D. Shvarts, *NRCN (Israel)*.

10:00AM GI1.00002 OMEGA Experiments on the Shock-Ignition ICF Concept , W. THEOBALD, Laboratory for Laser Energetics, U. of Rochester — Shock ignition[1] is an ICF concept that assembles thermonuclear fuel to high areal densities and then ignites it by launching a strong shock wave into the compressed fuel. The low-adiabat fuel assembly implodes with a velocity that is less than that required for hot-spot ignition. An intensity spike at the end of the main drive pulse generates a strong shock that is timed to meet the return shock bouncing back from the capsule center in the hot spot. The resulting fuel assembly is non-isobaric and will ignite with less energy than a conventional isobaric implosion.[1] Experiments to study the shock-ignition concept were performed on the OMEGA Laser System using 40-μm-thick, 0.9-mm-diam plastic shells filled with D_2 gas. The targets were driven by a relaxation adiabat-shaping laser pulse with a short picket pulse[2] and a high-intensity spike. The implosion was optimized by measuring the fuel assembly performance as a function of the timing of the picket pulse and the spike. Neutron-averaged areal densities of ~200 mg/cm^2 were measured. The shock-generated implosion showed fusion product yields enhanced by a factor of ~4 compared to an implosion without the spike. The measured neutron yield for a 25-atm fill, an adiabat of 1.6, and 17 kJ of laser energy was ~10% of the 1-D simulation prediction. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789. Contributors: R. Betti,* C. Stoeckl, K.S. Anderson,* J.A. Delettrez, V.Yu. Glebov, F.J. Marshall, D.N. Maywar, R.L. McCrory, D.D. Meyerhofer, P.B. Radha, T.C. Sangster, V.A. Smalyuk, A.A. Solodov,* B. Yaakobi, and C.D. Zhou, *UR/LLE*; J.A. Frenje, C.K. Li, R.D. Petrasso, and F.H. Séguin, *MIT-PSFC*; L.J. Perkins, *LLNL*; D. Shvarts, *NRCN (Israel)*. *Also at the Fusion Science Center for Extreme States of Matter and Fast Ignition.

[1] R. Betti *et al.*, Phys. Rev. Lett. **98**, 155001 (2007).
[2] K. Anderson and R. Betti, Phys. Plasmas **11**, 5 (2004).

10:30AM GI1.00003 Time-Resolved Absorption in Cryogenic and Room-Temperature, Direct-Drive Imploding Targets , W. SEKA, Laboratory for Laser Energetics, U. of Rochester — Time-resolved absorption has been measured in direct-drive-implosion experiments for various targets and pulse shapes using OMEGA's UV Laser System. These experiments reveal a number of interaction processes beyond inverse bremsstrahlung absorption. During the first 100 to 200 ps, evidence of enhanced absorption points toward resonance absorption. Depending on target material and pulse shapes, the absorption at times $t > 0.7$ ns is reduced compared to predictions by hydrodynamic simulations with flux-limited electron heat transport. This discrepancy may be partly due to uncertainties in the heat transport model. Scattered light spectra further indicate that beam-to-beam energy transfer with gain provided by stimulated Brillouin scattering (SBS) may also contribute. Evidence for two-plasmon-decay (TPD) instability is seen in almost all direct-drive-implosion experiments as evidenced by hard-x-ray and $3\omega/2$ emission. The TPD instability is driven particularly hard when the laser burns through the CD shell during the laser pulse in a cryogenic target implosion with the concomitant possibility of fast-electron preheat. This wealth of interaction processes will be discussed along with implications for future larger-scale experiments. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460. Contributors: D.H. Edgell, V.N. Goncharov, I.V. Igumenshchev, J.A. Delettrez, J. Myatt, A.V. Maximov, R.W. Short, C. Stoeckl, and T.C. Sangster.

11:00AM GI1.00004 Monoenergetic Proton Radiography of Electromagnetic Fields and Areal Density in Implosions and in Laser-Plasma-Interaction Experiments*,†

, R.D. PETRASSO, MIT Plasma Science and Fusion Center and University of Rochester Fusion Science Center — An isotropic monoenergetic proton backlighter source with matched detector has been utilized on the OMEGA laser system to accurately and sensitively study the following: First, MG fields generated by laser plasma interactions [1,2], both in the growth and decay phase, the latter associated with the development of instabilities that break 2-D symmetry; Second, the reconnection of MG fields in interacting, laser-generated magnetic bubbles [3]; Third, the fields and areal density evolution for cone-in-shell implosions[4]; and Fourth, the fields and areal density evolution of spherical implosions [5,6]. Complex field structures are observed during the implosions. Because of the precise energy of the 14.7 (3.0) MeV P backlighter, a result of the fusion reaction of D and ^{3}He (and DD) in an exploding pusher, a quantitative relationship exists between particle energy loss and areal density, and between particle deflections and field strength. Results of these experiments, as well as those currently being planned, such as accurate stopping power measurements in warm dense matter, will be presented.

[1] C. K. Li *et al.*, PRL 97 2006 ;
[2] C. K. Li *et al.*, PRL 99 2007;
[3] C. K. Li *et al.* (to be published in PRL);
[4] J. R. Rygg *et al.*, this conference;
[5] F. H. Seguin *et al.*, this conference;
[6] C. K. Li *et al.*, this conference.

* In collaboration with scientists from MIT, LLNL, and LLE.
† Supported by NLUF Contract DE-FG52-2005NA26011; and the Univ. of Rochester/Fusion Science Center Contract 412761-G.

11:30AM GI1.00005 Radiation energetics of inertial confinement fusion relevant wire-array z pinches[1]

, DANIEL SINARS, Sandia National Laboratories — The scaling of the radiation power and energy of z-pinch sources as a function of current and implosion time is of interest for z-pinch-driven, high-yield inertial confinement fusion applications [R.A. Vesey et al., Phys. Plasmas 14, 056302 (2007)]. Short implosion-time 20-mm diameter, 300-wire tungsten arrays maintain high peak x-ray powers on the 20 MA, 100-ns Z pulsed-power facility despite a reduction in peak current from 19 to 13 MA. The implosion kinetic energy is estimated using multiple diagnostics, including the first measurement of the imploding mass density profile of a wire- array z-pinch. The main radiation pulse (i.e., not including the late-time radiation) on tests with a 1-mm on-axis rod to limit the convergence may be explained solely by the kinetic energy flux. However, bare-axis tests require sub-mm convergence of the magnetic field and/or enhanced resistive heating. Sub-mm convergence is never seen in these arrays in the ~450 eV x-ray emission characteristic of the peak of the blackbody emission. Sub-mm widths are seen only in high- energy > 1 keV emission diagnostics. The latter images are characteristic of the high-energy tail in the emission spectrum that accounts for a substantial fraction of the total radiated energy and appears to be associated with small-area, high- temperature sources. The radiography and imaging data discussed here are presently being used to provide strong constraints for simulations beyond just the radiated power and energy. In collaboration with: M.E. Cuneo, S.V. Lebedev (Imperial College), R.W. Lemke, E.M. Waisman, W.A. Stygar, B. Jones, M.C. Jones, J.L. Porter, and D.F. Wenger.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the National Nuclear Security Administration under DE-AC04-94AL85000.

12:00PM GI1.00006 Investigation of trailing mass in Z-pinch implosions and comparison to experiment[1]

, EDMUND YU, Sandia National Laboratories — Wire-array Z pinches represent efficient, high-power x-ray sources with application to inertial confinement fusion, high energy density plasmas, and laboratory astrophysics. The first stage of a wire-array Z pinch is described by a mass ablation phase, during which stationary wires cook off material, which is then accelerated radially inwards by the JxB force. The mass injection rate varies axially and azimuthally, so that once the ablation phase concludes, the subsequent implosion is highly 3D in nature. In particular, a network of trailing mass and current is left behind the imploding plasma sheath, which can significantly affect pinch performance. In this work we focus on the implosion phase, electing to model the mass ablation via a mass injection scheme. Such a scheme has a number of injection parameters, but this freedom also allows us to gain understanding into the nature of the trailing mass network. For instance, a new result illustrates the role of azimuthal correlation. For an implosion which is 100% azimuthally correlated (corresponding to an azimuthally symmetric 2D r-z problem), current is forced to flow on the imploding plasma sheath, resulting in strong Rayleigh-Taylor (RT) growth. If, however, the implosion is not azimuthally symmetric, the additional azimuthal degree of freedom opens up new conducting paths of lower magnetic energy through the trailing mass network, effectively reducing RT growth. Consequently the 3D implosion experiences lower RT growth than the 2D r-z equivalent, and actually results in a more shell-like implosion. A second major goal of this work is to constrain the injection parameters by comparison to a well-diagnosed experimental data set, in which array mass was varied. In collaboration with R. Lemke, M. Desjarlais, M. Cuneo, C. Jennings, D. Sinars, E. Waisman

[1]Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Tuesday, November 13, 2007 9:30AM - 12:30PM –
Session GI2 Alternates Rosen Centre Hotel Salon 3/4

9:30AM GI2.00001 Extension of High-Ion-Temperature Regime in the Large Helical Device (LHD)[1]

, MASAYUKI YOKOYAMA[2], National Institute for Fusion Science — The production of high-ion-temperature hydrogen plasmas was successfully demonstrated in the LHD. The ion temperature (Ti) exceeded 5 keV (the record value in helical plasmas) at an average plasma density (n_e) of $1.2\text{x}10^{19}\text{m}^{-3}$ and also achieved 3 keV at $n_e \sim 4\text{x}10^{19}\text{m}^{-3}$. This achievement demonstrated the capability of high-ion-temperature plasma confinement in helical devices. The total injection power of neutral beams of 20 MW (3 parallel and 1 perpendicular injections) and ion cyclotron heating power of about 2 MW was applied in reduced helical-ripple magnetic configurations with Rax in the range of 3.575-3.65 m and B of 2.7-2.85 T. Here Rax is the vacuum magnetic axis position. High-Ti plasmas typically have large toroidal velocity, Vt, of order 50 km/s in the core region, accompanied by an increase of the Ti-gradient.
The measured core density of carbon-impurity ions strongly drops as the core-Ti increases. This implies that carbon-impurity ions are expelled from the core region. This unique feature may provide an efficient knob to avoid the impurity accumulation in reactor-relevant helical plasmas. Transport analysis has been performed, including comparison with relevant theories. In these high-Ti plasmas, the ions are in $1/\nu$ regime and the neoclassical ambipolar Er is expected to be negative (ion-root). This prediction indicates that the hollow impurity profile (usually anticipated from the positive Er (electron-root)) must be due to effects beyond neoclassical transport theory. The role of the large Vt in the improved ion heat confinement, with the viewpoint of plasma viscosity structure in three-dimensional magnetic configurations, will be discussed.

[1]This work is supported by the collaboration program of NIFS (NIFS07KLDD011) and by the Grants-in-aid from the Japanese Ministry of Education, Culture, Sports, Science, and Technology (18760638) for M.Y.
[2]for the LHD Experimental Group

10:00AM GI2.00002 Theoretical and experimental studies of high-beta plasmas formed by odd-parity rotating magnetic fields[1] , SAMUEL COHEN, Princeton Plasma Physics Laboratory — Hamiltonian simulations of ion and electron heating by odd-parity rotating magnetic fields applied to FRC plasmas have predicted rapid heating of both electrons and ions to multi-keV temperatures, even at low relative RMF strengths. Both the onset of heating and saturation of energy have been explained by perturbation analysis in stochastic theory. These simulations assumed full RMF penetration to the major axis and collisionless particle trajectories, the latter expected in fusion reactor. However, most present RMF/FRC experiments do not achieve full RMF penetration and operate in a low-temperature collisional regime, far from fusion-reactor conditions. Recent experiments at Princeton, which employ commercial off-the-shelf hardware and non-invasive diagnostics and which use, for the first time in FRC research, remote divertor chambers, have achieved a thousand-fold reduction in collisionality to below 0.001, volume-averaged beta above 0.5, electron temperatures above 200 eV, and full penetration of the RMF while avoiding the radiation barrier encountered by other RMF/FRC experiments. Comparisons between theory and experiment show the important role of infrequent collisions, particularly with neutrals. Motivations for a superconducting next-step FRC and design considerations for a car-sized practical FRC reactor will be described.

[1]This work was supported, in part, by the US Department of Energy Contract No. DE-AC02-76-CHO-3073.

10:30AM GI2.00003 Higher Temperature Steady-State FRCs Formed and Sustained by Rotating Magnetic Fields in the New TCS-Upgrade Device[1] , HOUYANG GUO, University of Washington — Previous work in the Translation, Confinement, and Sustainment (TCS) device has demonstrated the formation and steady-state sustainment of FRCs by rotating magnetic fields (RMF). The RMF was shown to provide complete FRC stability and good particle confinement. Simple theory shows that the particle density is set primarily by the applied RMF torque, but that the plasma temperature is separately determined by power balance. In TCS this temperature was limited to several 10s of eV due to high impurity content. A new upgraded device, TCSU, with a bakable, ultra-high vacuum chamber was built to reduce these impurities and overall recycling. Spectacular improvements were obtained in the first month of TCSU operation, with temperatures increasing to well over 100 eV. The higher temperatures resulted in higher magnetic fields and toroidal currents without higher RMF power inputs, indicating improvements in current drive efficiency and energy confinement time with temperature. These results were obtained with simple, even-parity RMF antennas, which cause field line opening. Results with both odd-parity antennas, which can achieve complete field line closure and reduce fundamental non-radiative energy loss rates, as well as with advanced wall conditioning methods will also be reported on.

[1]This work was funded by the U.S. Department of Energy

11:00AM GI2.00004 Gyrokinetic simulations of plasma turbulence, transport and zonal flows in a closed field line geometry[1] , BARRETT ROGERS, Department of Physics and Astronomy, Dartmouth — We present nonlinear gyrokinetic simulations of small-scale plasma turbulence and transport in closed field-line geometries relevant to the Levitated Dipole Experiment (LDX) and planetary magnetospheres: the Z-pinch and the ring-dipole. As in toroidal geometries, the instabilities present in the system depend on the steepness of the plasma pressure gradient: for sufficiently steep gradients, the system is unstable to ideal interchange modes, while for weaker gradients, short wavelength non-MHD modes at the ion gyro-radius scale (entropy modes) typically dominate. Considering the latter, ideally-stable case at low plasma beta, we find an enormous variation in the nonlinear dynamics and particle transport as a function of the density and temperature gradients and the plasma collisionality. This variation is explained in part by the damping and stability properties of spontaneously formed zonal flows in the system. As in toroidal systems, the zonal flows can lead to a strong nonlinear suppression of transport below a critical gradient that is determined by the stability of the zonal flows.

[1]This work is supported by grants from the US Department of Energy

11:30AM GI2.00005 Magnetic Field Generation and Energy Confinement with $T_e > 500$ eV in the SSPX Spheromak[1] , B. HUDSON[2], Lawrence Livermore National Laboratory — The understanding of confinement and energy transport in spheromaks is key the understanding the physics of spheromak formation and self-organization as well as addressing the feasibility of the concept as a reactor scenario. In the Sustained Spheromak Physics eXperiment (SSPX), increased understanding of the physics in building and sustaining self-organized magnetic equilibria has resulted in record electron temperatures $T_e > 500$ eV and plasma currents of ~ 1 MA on the magnetic axis. We find that the highest edge magnetic field magnitudes (and correspondingly high T_e) is achieved when $\lambda = \frac{\mu_0 I_{gun}}{\Psi_{gun}}$ is near (but slightly below) the Kruskal-Shafranov instability limit $\lambda_{KS} \cong \frac{2\pi}{L} \cong 12.6\, m^{-1}$ where L is the length of the flux-conserver (0.5 m). Building on previously reported results, power-balance analysis has shown levels of electron thermal transport $\chi_e < 1$ m^2/s, indicating good confinement and closed flux surfaces. With the addition of a modular capacitor bank we are able to highly tailor the gun current to take advantage of the sensitive dependence of spheromak performance on the plasma λ. When in this optimum operating range we also find that the efficiency of field build-up (defined as the ratio of edge poloidal magnetic field to gun current) is increased 20% over prior results, to $\sim$1.0 T/MA. Additionally this brings the efficiency of spheromak formation into numerical agreement with results from the NIMROD 3-D MHD code. Plasma energy evolution has been studied by taking time-resolved measurements of T_e(r) and n_e(r) indicating a distinct and robust feature of spheromak formation; a hollow-to-peaked temperature transition with an inverse relationship to the electron density. This feature, as well as sub-microsecond transport, is being studied with the upgrade of the Thomson scattering diagnostic to double-pulse operation. We also present recent results of the impact of charge-exchange losses on overall power balance and estimates of the plasma ion temperature as measured with a neutral particle analyzer.

[1]Work performed under the auspices of the US DOE by University of California Lawrence Livermore National Laboratory under contract W–7405–ENG–48.

[2]In association with B.I. Cohen, E.B. Hooper, J. Johnson, H.S. McLean, E. Mezonlin, J.M. Moller, C. Romero-Talamas, R.D. Wood

12:00PM GI2.00006 High confinement in fusion oriented plasmas with kV-order potential, ion, and electron temperatures with controlled radial turbulent transport in GAMMA 10 , TERUJI CHO, Plasma Research Centre, University of Tsukuba, Ibaraki 305-8577, Japan — The tandem mirror system has achieved improved energy confinement times (> 60-90 ms) with radial transport dominating the Pastukhov axial energy confinement time (> 100 ms). This high confinement regime establishes a proof of principle that the combination of electrostatic and magnetic mirror confinement can successfully insulate electrons from thermal ions. ECH controlled hot-layer formation facilitates plasma-rotation profile formation with a radially localized high-vorticity layer. In the vicinity of the layer, a radial transport barrier is formed [1], showing similar properties to ITB in toroidal plasmas. Coaxially nested intense E(r)×B sheared flow [2] in the GAMMA 10 core plasma realizes an upgraded stable regime having (i) > 0.75 keV bulk central electron temperature with (ii) an achievement of larger stored energy for axially potential-confined ions exceeding that (i.e., diamagnetism) for central magnetically confined ions (≈ 7 keV). The radially sheared flow having peak-on-axis high vorticity guards and improves whole core plasma confinement, and is controlled by (iii) improved ≈ 3 kV ion-confining potential due to simultaneous central and plug ECH. X-ray imaging of the suppression of turbulent structures [1-3] will be shown [1,2].

[1] T. Cho et al., Phys. Rev. Lett. **97**, 055001 (2006).
[2] T. Cho et al., Phys. Rev. Lett. **94**, 085002 (2005).
[3] J. Pratt and W. Horton, Phys. Plasmas **13**, 042513 (2006).

Collaborators; W. Horton[1], J. Pratt[1], M. Hirata, J. Kohagura, T. Numakura, H. Hojo, M. Ichimura, A. Itakura, T. Kariya, I. Katanuma, R. Minami, Y. Nakashima, M. Yoshikawa, Y. Miyata, Y. Yamaguchi, T. Imai, V. P. Pastukhov[2], S. Miyoshi, GAMMA 10 Group ([1]IFS, Univ. Texas at Austin, [2]Kurchatov Institute, Russia)

Tuesday, November 13, 2007 9:30AM - 12:30PM –
Session GO3 DIII-D Tokamak Rosen Centre Hotel Salon 9/10

9:30AM GO3.00001 Overview of Recent DIII-D Experimental Results[1] , C.M. GREENFIELD, General Atomics, DIII-D NATIONAL TEAM — The 2007 DIII-D experimental campaign focuses on resolving issues of importance to the ongoing ITER Design Review. Recent experiments have established the importance of island overlap for ELM suppression and confirmed the previous observation of a low rotation threshold for RWM stabilization in AT plasmas with $\beta_N \approx 4$, providing critical information for the design of internal coil systems for RWM and ELM control in ITER. Experiments simulating the ITER startup scenario with an outer wall limited plasma exhibit high internal inductance during the current ramp, potentially presenting challenges for vertical stability in ITER. Studies performed in the high performance hybrid scenario establish that pedestal pressure increases with triangularity and plasma β, but with little dependence on plasma rotation. Increasing T_e/T_i with ECH results in increased low to intermediate k fluctuations, but little change in confinement. In other studies, radial profiles of electron temperature and density fluctuations have been simultaneously measured, and are observed to behave similarly.

[1]Supported by the US DOE under DE-FG02-04ER54698.

9:42AM GO3.00002 Effects of Resonant Magnetic Perturbations on Edge Turbulence and Profiles in DIII-D[1] , J.A. BOEDO, D.L. RUDAKOV, I. JOSEPH, R.A. MOYER, UCSD, G.R. MCKEE, U. Wisc-Madison, D. REISER, Juelich, T.E. EVANS, W.P. WEST, GA, J.G. WATKINS, SNL — Resonant magnetic perturbations (RMPs) applied to the plasma edge can cause changes in average density and in the turbulence measured by various diagnostics at the edge and scrape-off layer (SOL). The change in turbulence can modify the edge profiles, which can affect the RMP ELM suppression, which is important for ITER. Two main regimes have been explored: 1) low power and collisionality discharges, where it is seen that the RMPs affect the edge profiles across the SOL and into the core; and 2) high power, varying (low, medium and high) collisionality discharges where the average density can increase or decrease but the turbulence in the SOL always increases. In these discharges, the pedestal fluctuations can increase or decrease in narrowly localized radial regions near the pedestal top. When the RMP are rotated toroidally, the fluctuations change amplitude and/or location, indicating that the RMP-induced changes are toroidally localized.

[1]Supported by US DOE under DE-FG02-04ER54698, DE-FG02-89ER53296, DE-FC02-04ER54758, and DE-AC04-94AL85000.

9:54AM GO3.00003 Resistive Wall Mode and Plasma Stability at High β and Slow Rotation[1] , A.M. GAROFALO, H. REIMERDES, M.J. LANCTOT, Columbia U., M. OKABAYASHI, H. TAKAHASHI, PPPL, G.L. JACKSON, R.J. GROEBNER, R.J. LA HAYE, E.J. STRAIT, GA, Y. IN, J. KIM, FAR-TECH, Inc. — DIII-D experiments extended the observation of resistive wall mode (RWM) stabilization by slow plasma rotation to various scenarios, including high-β advanced tokamak scenarios, and confirmed that magnetic feedback increases stability against equilibrium disturbances, such as large ELMs. At high β, magnetic disturbances that resonant with marginally stable RWM can lead, depending on torque input and momentum confinement, to loss of torque balance followed by plasma locking, perturbation growth, and confinement loss. Reconnection may take place once plasma is locked. Magnetic feedback can maintain or quickly restore axisymmetry and avoid locking. With very low torque input, however, error field threshold for locking may be below feedback sensitivity. Residual uncorrected error fields may explain why minimum sustainable rotation profiles are generally higher than those predicted by ideal-plasma RWM stability theory.

[1]Supported by the US DOE under DE-FG02-89ER53297, DE-AC02-76CH03073, DE-FC02-04ER54698, and DE-FG02-03ER83657.

10:06AM GO3.00004 Plasma Initiation and Startup in DIII-D Simulating the ITER Scenario[1] , G.L. JACKSON, T.C. LUCE, J.R. FERRON, A.W. HYATT, T.W. PETRIE, W.P. WEST, GA, T.A. CASPER, LLNL, E.A. LAZARUS, ORNL, R.A. MOYER, D.L. RUDAKOV, UCSD — DIII-D similarity experiments have investigated the ITER baseline startup scenario, specifically outer wall low field side (LFS) limited discharges with an I_p ramp at constant safety factor, q_{95}. Optimizing startup may be necessary for ITER advanced tokamak (AT) discharges and to minimize limiter heating. Although I_p initiation in DIII-D occurred near the inner wall (in the region of highest $E_\phi L$, where E_ϕ is the inductive electric field and L is the wall connection length), it moved outward in <5 ms (scaling to ~0.25 s in ITER) and then limited on the LFS limiters. In this ITER-like shape, $I_p$was ramped to ≤1.2 MA with q_{95} held constant during the limited phase by a simultaneous I_p and κ ramp. In addition to presenting LFS startup results, we will discuss other startup issues for ITER, i.e. limiter heat flux, compatibility with AT scenarios, sawteeth, and vertical stability. Startup scenarios other than constant q_{95} will also be presented.

[1]Supported by the US DOE under DE-FC02-04ER54758, W-7405-ENG-48, DE-AC05-00OR22725, and DE-FG02-094ER54758.

10:18AM GO3.00005 High Performance Operation on DIII-D With Reduced Frequency of Wall Conditioning[1]

, W.P. WEST, N.H. BROOKS, A.W. HYATT, G.L. JACKSON, C.M. GREENFIELD, P.A. POLITZER, M.R. WADE, General Atomics, M. GROTH, LLNL — Recent DIII-D experiments have demonstrated the capability to obtain high performance plasmas, ($\beta_N H_{ITER89}/q_{95}^2 \sim$ 0.38), in both hybrid and steady-state scenarios over an extended operations period (6000 plasma seconds) with no intervening boronization or bakes. Over the same period, impurity influx monitored with daily reference shots remains at low levels. With adequate divertor pumping, good hybrid performance can also be maintained in several sequential discharges with no between-shot helium glow. These findings on DIII-D, which has >95% graphite plasma facing wall, are in sharp contrast to recent studies on tokamaks with high-Z metallic walls, where frequent boronizations are found necessary to prevent radiative collapse of high-confinement, high-beta discharges [1,2].

[1] B. Lipschultz, *et al.,* Phys. Plasma **13**, 056117 (2006).
[2] R. Neu, *et al.,* J. Nucl. Mater. **363-365**, 52 (2007).

[1]Supported by the US DOE under DE-FC02-04ER54698 and W-7405-ENG-48.

10:30AM GO3.00006 Observation of Carbon Dust in the DIII-D Divertor and SOL[1]

, D.L. RUDAKOV, A.YU. PIGAROV, R.D. SMIRNOV, J.H. YU, UCSD, W.P. WEST, C.P.C. WONG, GA, M. GROTH, M.E. FENSTERMACHER, LLNL, W.M. SOLOMON, PPPL — Dust accumulation is a serious safety concern for ITER. In DIII-D carbon dust is observed in divertor and scrape-off layer (SOL) by optical imaging. After an extended entry vent, thousands of dust particles are observed in the first 2-3 plasma discharges. Individual particles moving at velocities up to ∼500 m/s, and breakup of larger particles into pieces are observed. After ∼70 discharges, dust levels are reduced to a few observed events per discharge except in discharges with disruptions that produce significant amounts of dust. Using the divertor materials evaluation system (DiMES), micron-sized carbon dust is injected into DIII-D ELMing H-mode discharges. When the outer divertor strikepoint is swept onto DiMES, ∼2% of the dust carbon content penetrates the core, raising the core carbon density by a factor of ∼4. Dust particles from the injection are observed in the outboard SOL. The observed dust trajectories and velocities are in qualitative agreement with the modeling of the 3D DustT code.

[1]Work supported by US DOE under DE-FG02-04ER54758, DE-FC02-04ER54698, W-7405-ENG-48, DE-AC02-76CH03073.

10:42AM GO3.00007 Extension of DIII-D Hybrid Plasmas Towards Operation with $T_e \sim T_i$ and Low Rotation[1]

, E.J. DOYLE, University of California-Los Angeles, THE HYBRID SCENARIO THRUST TEAM — DIII-D hybrid plasmas typically operate in a hot ion mode ($T_i > T_e$) with high plasma rotation, which tend to reduce turbulent transport. Recent DIII-D experiments extend hybrid operation to more reactor relevant conditions, with low plasma rotation and $T_e \approx T_i$. Using electron cyclotron (EC) heating to replace part of the neutral beam heating, T_e/T_i has been increased to ∼0.8 in hybrid plasmas with β_N=2.6, with minimal effect on confinement time and a modest reduction in plasma rotation. The plasma turbulence level increased significantly in the EC heated hybrid plasmas, at both low and intermediate wavenumbers, as measured by BES and FIR scattering systems. Central Mach number in DIII-D hybrid plasmas has been scanned across a wide range, from 0.07 to 0.6. At low rotation, the confinement factor H_{89} degrades, typically by 10%-30%. Transport modeling using the GLF23 code indicates that the change in transport with rotation can be accounted for by changes in the ExB shearing rate.

[1]Work supported by US DOE under DE-FG03-01ER54615 and DE-FC02-04ER54698.

10:54AM GO3.00008 Towards Demonstration of Steady-State High-Performance Scenarios in DIII-D[1]

, T.C. LUCE, J.R. FERRON, P.A. POLITZER, C.M. GREENFIELD, A.W. HYATT, G.L. JACKSON, T.W. PETRIE, R.I. PINSKER, W.P. WEST, GA, A.M. GAROFALO, R. REIMERDES, Columbia U., T.A. CASPER, C.T. HOLCOMB, M.A. MAKOWSKI, LLNL, M. OKABAYASHI, PPPL, M. MURAKAMI, J.M. PARK, ORNL, E.J. DOYLE, UCLA, S. IDE, JAEA — Experiments on advanced scenarios in DIII-D are focused on extension to the resistive time scale, optimization, and exploration for higher performance. Optimization studies use ECCD and counter-NBI to modify the q profile shape, looking at the effect on MHD stability and bootstrap current. Feedback control of the current formation is also a key element of optimization. Closed-loop experiments and modeling of open-loop tests have been carried out. Experiments seeking β_N=5 used two approaches – high q_{min} with rotational stabilization and high magnetic shear. High shear experiments achieved $\beta_N >$ 4.5 transiently. Attempts to use the longer-pulse (5 s) ECCD system to extend the duration of noninductive high-performance discharges to resistive equilibrium will be presented.

[1]Supported by the US DOE under DE-FC02-04ER54698, DE-FG02-89ER53297, W-7405-ENG-48, DE-AC02-76CH03073, DE-AC05-00OR22725, and DE-FG03-01ER54615.

11:06AM GO3.00009 Integrated Scenario Modeling for Advanced Scenario Development in DIII-D[1]

, J.M. PARK, M. MURAKAMI, Oak Ridge National Laboratory, H.E. ST JOHN, L.L. LAO, J.R. FERRON, R. PRATER, General Atomics — Integrated predictive simulations are carried out to guide design of Advanced Tokamak (AT) experiments with upgraded DIII-D hardware. Recent advances in the theory-based modeling include improved transport models for particle and momentum and integration with realistic feedback control algorithms as used in the DIII-D experiments. The modeling tools are validated successfully against recent AT experiments: (i) sustained (∼2 s) operation with $\beta_N \approx$ 4 (50% above the no-wall stability limit) with internal transport barrier using toroidal field ramp, and (ii) fully noninductive operation [in-principle steady state (SS)] with $\beta_N \approx$ 3.5. Present simulation efforts focus on optimizing SS conditions at higher β by utilizing the increased electron cyclotron and fast wave power in a pumped double-null configuration, indicating that SS can be achieved with $\beta_N \geq$ 4 for longer than a current relaxation time using the upgraded hardware planned for DIII-D.

[1]Work supported by US DOE under DE-AC05-00OR22725 and DE-FC02-04ER54698

11:18AM GO3.00010 Locked Neoclassical Tearing Mode Control on DIII-D by Electron Cyclotron Current Drive and Magnetic Perturbations[1]

, F. VOLPE, ORAU, R.J. LA HAYE, R. PRATER, E.J. STRAIT, General Atomics — Magnetic perturbations were used at DIII-D to unlock, reposition or spin locked tearing modes and so assist their electron cyclotron durrent drive (ECCD) stabilization. While the island was slowly (0.66 Hz) dragged in the toroidal direction and illuminated by 1.3 MW ECCD, current was alternatively driven in its O-point and X-point. Correspondingly, a modulation of the mode amplitude by up to a factor 2 was observed, consistent with the stabilizing/destabilizing effect of ECCD in the O/X point. Faster sustained rotation, at up to 180 Hz, was also demonstrated. This brings the locked mode case into the well-studied rotating neoclassical tearing mode (NTM) case. It also opens up the possibility to synchronize and phase-lock the ECCD modulation to the entrained mode rotation, which is simpler than adapting the ECCD to the natural mode frequency and phase.

[1]Supported by the US DOE under DE-FC02-04ER54698.

11:30AM GO3.00011 Local Turbulence Suppression and Flow Shear Dynamics During q_{min}-Triggered Internal Transport Barriers[1] , M.W. SHAFER, G.R. MCKEE, D.J. SCHLOSSBERG, U. Wisc.-Madison, M.E. AUSTIN, U. Texas-Austin, R.E. WALTZ, J. CANDY, General Atomics — Turbulence is observed to transiently decrease locally during the formation of internal transport barriers (ITBs) following the appearance of low-order rational q_{min} surfaces in negative central shear discharges on DIII-D. Simultaneously, increased poloidal flow shear is observed. To further study this phenomenon, localized 2D density fluctuation measurements of turbulence and turbulence flow were obtained over $0.3 < r/a < 0.7$ via the high-sensitivity beam emission spectroscopy diagnostic. Both the reduction in fluctuations and the poloidal velocity shear are found to propagate radially outward at about 1 m/s. Initial observations suggest that these effects follow the q=2 surface. Related GYRO simulations suggest transient zonal flows form near the q=2 surface to trigger these ITBs. High-frequency poloidal velocity measurements will be used to examine this mechanism.

[1]Supported by the US DOE under DE-FG02-89ER53296, DE-FG03-97ER54415, and DE-FG03-95ER54309.

11:42AM GO3.00012 Role of Pedestal in Hybrid Discharges in DIII-D[1] , R.J. GROEBNER, General Atomics, C.F. MAGGI, IPP-Garching, C.C. PETTY, A.W. LEONARD, T.H. OSBORNE, J.R. FERRON, A.W. HYATT, P.A. POLITZER, J.C. DEBOO, W.P. WEST, B.D. BRAY, GA — Studies of hybrid discharges in DIII-D show that the best performance in the hybrid regime is due to a combination of pedestal and core effects. The role of the H-mode pedestal in this regime has been studied with scans of β_N (heating power) in discharges with 2 different values of average triangularity δ = 0.25 and 0.50. For both δs, the pedestal beta, as determined from measurements of pedestal temperatures and densities, increased as the global β was increased. For a given value of β_N, discharges with the higher delta had significantly higher values of pedestal β and also of H98(y,2) than discharges with the lower δ, a result which is consistent with improved MHD stability of the pedestal expected at higher δ. However, at the highest values of β_N in the high δ discharges, some of the increase in core energy with increased power cannot be attributed directly to changes in the pedestal. Thus, both core and pedestal physics are important in determining the global confinement achieved in hybrid operation.

[1]Work supported by U.S. DOE under DE-FC02-04ER54698.

11:54AM GO3.00013 Effect of Reverse Shear Alfvén Eigenmodes on Delivered Neutral Beam Torque[1] , W.M. SOLOMON, R.V. BUDNY, G.J. KRAMER, D. MIKKELSEN, R. NAZIKIAN, S.D. SCOTT, M.C. ZARNSTORFF, PPPL, K.H. BURRELL, J.S. DEGRASSIE, C.C. PETTY, M.A. VAN ZEELAND, GA — Modifications to the torque deposition profile from neutral beam injection is investigated under varying levels of reverse shear Alfvén eigenmode (RSAE) activity. The rotation profile is found to be altered in the presence of strong RSAE activity, but the total mechanical angular momentum appears relatively independent of the RSAE intensity. This indicates that the neutral beam ions are being redistributed in the presence of RSAEs, rather than lost, consistent with present understanding of how RSAEs affect fast ions. Analysis of the momentum transport channel provides a technique for determining how the fast ions are redistributed. In particular, by matching the local momentum diffusivity and global momentum confinement time for plasmas with strong RSAEs with plasmas without RSAEs, one can precisely infer the modification to the neutral beam torque profile from the classical prediction, and estimate the anomalous fast ion diffusion caused by the RSAEs.

[1]Work supported by US DOE under DE-FC02-04ER54698 and DE-AC02-76CH03073.

12:06PM GO3.00014 DIII-D Quiescent H-mode Experiments With Co Plus Counter Neutral Beam Injection[1] , K.H. BURRELL, W.P. WEST, P. GOHIL, T.H. OSBORNE, P.B. SNYDER, GA, M.E. FENSTERMACHER, LLNL, W.M. SOLOMON, PPPL — QH-mode discharges have all the confinement advantages of H-mode with none of the detrimental effects caused by ELMs. Edge density control is instead provided by an edge MHD mode, the edge harmonic oscillation (EHO). The edge parameter operating regime in QH-mode is consistent with peeling-ballooning mode stability calculations. Using these as a guide, we developed a double-null plasma shape that has a much broader range of edge stability compared to the upper single null plasmas used previously. Altering the edge rotation in these plasmas using the co plus counter NBI capability on DIII-D, we could control the edge density and pressure by a factor of $\sim$2 while retaining the ELM-free state. The change in rotation alters the EHO and, apparently, the edge particle transport. Pedestal densities up to $^1/_2$ the Greenwald density have been achieved in these plasmas, which is the same as the ELMing H-mode value. Accordingly, we now have a technique for actively controlling edge pressure in QH-mode plasmas.

[1]Work supported by US DOE under DE-FC02-04ER54698, W-7405-ENG-48, and DE-AC02-76CH03073.

12:18PM GO3.00015 Prediction of Sawtooth Periods in Fast-Wave Heated DIII-D Experiments Using Extensions of the Porcelli Model[1] , A.D. TURNBULL, M. CHOI, L.L. LAO, V.S. CHAN, M.S. CHU, General Atomics, Y.M. JEON, ORISE, G. LI, Q. REN, ASIPP, N. GORELENKOV, PPPL — Validation of a predictive sawtooth model is important for burning plasma experiments such as ITER. The Porcelli model using simplified expressions for the key contributions has been found to predict average sawtooth periods reasonably well in existing tokamaks. We evaluate this model using realistic models for the ideal MHD contribution from GATO, and a nonisotropic fast ion contribution using ORBIT-RF and TORIC for the rf-modified fast-ion pressure. Application to the first giant sawtooth cycle in a DIII-D discharge where beam ions accelerated by fast waves modify the sawteeth shows the model can predict the crash time consistent with the experimental crash. The stabilizing contributions depend strongly on uncertainties in the magnetic shear at q=1 and the fast ion poloidal beta. The model will be also applied to other sawteeth in the same discharge and compared to predictions from the more complete NOVA-K stability code with full anistropy.

[1]Supported by the US DOE under DE-FG03-95ER54309, DE-AC05-76CH00033, and DE-AC02-76CH03073.

Tuesday, November 13, 2007 9:30AM - 12:30PM – Session GO6 ICF/HEDP Diagnostics Rosen Centre Hotel Salon 5/6

9:30AM GO6.00001 Magnetic Field Measurements in Wire-Array Z-Pinches using Magneto-Optically Active Waveguides , WASIF SYED, DAVID HAMMER, MICHAL LIPSON, Cornell University, Ithaca, NY — Understanding the magnetic field topology in wire-array Z-pinches as a function of time is of great significance to understanding these high-energy density plasmas. We are developing techniques to measure magnetic fields as a function of space and time using Faraday rotation of a single longitudinal mode (SLM) laser through a magneto-optically active bulk waveguide (terbium borate glass) placed adjacent to, or within, the wire array in experiments on the COBRA pulsed power generator [1]. We have measured fields >10 T with 100 ns rise times outside of a wire-array for the entire duration of the current pulse and as much as $\sim$2 T inside a wire-array for $\sim$40 ns from the start of current. This is the first time that such rapidly varying and large fields have been measured using these materials. We will also present our progress on field measurements using an optical fiber sensor and a very small "thin film waveguide" coupled to a fiber optic system. In a dense Z-pinch, these sensing devices may not survive for long but may provide the magnetic field at the position of the sensor for a greater fraction of the current pulse than magnetic probes, with which we compare our results. This research was sponsored by NNSA under SSAA program via DOE Coop Agreement DE-F03-02NA00057.

[1] W. Syed, D. A. Hammer, & M. Lipson, 34^{th} ICOPS & 16^{th} PPPS, Albuquerque, NM, June 2007.

9:42AM GO6.00002 Time-Gated X Pinch Backlighting of Imploding Wire Array Z Pinches Using MCP[1] , ISAAC BLESENER, KATE BELL, DAVE CHALENSKI, JON DOUGLASS, PAT KNAPP, RYAN MCBRIDE, SERGEI PIKUZ, TANIA SHELKOVENKO, BRUCE KUSSE, Cornell University, SIMON BOTT, DAVID HAAS, UTAKO UEDA, UCSD — X-ray backlighting of imploding Z pinches is difficult because the Z pinch generally produces much more radiation than the backlighting source, thus saturating the film. Monochromatic x-ray backlighting is currently the only way to image the axis of an imploding Z pinch. Other techniques exist, but require modifying the Z pinch in a way that prevents it from radiating strongly. One promising technique is to use a microchannel plate (MCP) detector to gate the exposure. This way, the Z pinch can be allowed to form and radiate without modification. A 12.5 micron Ti filter allows energies in the range of 3-5 keV to reach the MCP which acts as a shutter to stop exposure of the film before the Z pinch radiates in that range. Presented here are the results of sensitivity measurements of the MCP as well as preliminary experiments imaging imploding Al and W arrays on the COBRA pulser.

[1]Research supported by DOE grant DE-FG03-98ER54496, by Sandia National Laboratories contract AO258, and by the NNSA Stockpile Stewardship Academic Alliances program under DOE Cooperative Agreement DE-FC03-02NA00057

9:54AM GO6.00003 Electron density determination in a MgFe dense plasma via Stark-broadening analysis[1] , ROBERTO MANCINI, University of Nevada, Reno, JAMES BAILEY, GREGORY ROCHAU, PATRICK LAKE, Sandia National Laboratories, CARLOS IGLESIAS, Lawrence Livermore National Laboratory, JOSEPH ABDALLAH, Los Alamos National Laboratory, JOSEPH MACFARLANE, IGOR GOLOVKIN, PING WANG, Prism Computational Sciences — Recent measurements of L-shell Fe opacity at temperatures above 100eV were performed at Sandia National Laboratories by recording x-ray transmission through a MgFe two-element plasma. While the observation of line absorption in Fe L-shell transitions was an important goal of the experiment, the Stark-broadened line absorption in Mg K-shell transitions provided an independent spectral signature for electron density determination. Indeed, at the expected 10^{21} cm^{-3}to 10^{22} cm^{-3}electron density range, Stark-broadening dominates the line width of several Mg K-shell transitions. We discuss the Mg K-shell line absorption spectrum, the calculation of Stark-broadened absorption line shapes, and their application to data analysis and electron density extraction.

[1]This work is supported by a contract from SNL

10:06AM GO6.00004 Experimental Stark widths of the 3p-3s transition of Ne VIII[1] , SIEGFRIED GLENZER, JAMES ROSS, Lawrence Livermore National Laboratory, University of California, P.O. Box 808, Livermore, California 94551, HANS KUNZE, Institute for Experimental Physics, Ruhr University Bochum, 44780 Bochum, Germany — We report measurements of the line width of the 3p-3s transition in Ne VIII in laser-produced gas jet plasmas. The density is inferred from the Paschen-alpha line in He II, the temperature from Thomson scattering. Preliminary results confirm measurements in pinch and pulsed-arc plasmas indicating that newest quantum-mechanical calculations underestimate the line width by a factor of two.

[1]This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

10:18AM GO6.00005 Development of Compton radiography using multi-pulse high-Z backlighters[1] , RICCARDO TOMMASINI, S. HATCHETT, H-S. PARK, P. PATEL, B MADDOX, S. LE PAPE, B. REMINGTON, M. KEY, M. TABAK, J. KOCH, O. LANDEN, N. IZUMI, A. MACKINNON, Lawrence Livermore National Laboratory, J. SEELY, G. HOLLAND, Naval Research Laboratory, L. HUDSON, C. SZABO, National Institute of Standards and Technology — Radiography of the cold dense fuel will be a valuable diagnostic for imploding inertial confinement fusion targets at the National Ignition Facility (NIF). For x-rays with energies between 30 and 200 keV, the main opacity will be Compton scattering. We report on experiments to characterize x-ray emission from low- to high-Z planar foils irradiated by intense picosecond laser pulses. Spectra generated by a sequence of elements from Mo to Pb, with line and continuum emission up to 100 keV, have been recorded using a Charged Coupled Device (CCD) in single hit regime and a crystal spectrometer. We discuss the results and implications for the design of the experiments at the NIF.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

10:30AM GO6.00006 Neutron-Induced Signal Measurements in Cables on OMEGA , V.YU. GLEBOV, T.C. SANGSTER, C. STOECKL, S. ROBERTS, W. BITTLE, Laboratory for Laser Energetics, U. of Rochester, R.A. LERCHE, LLNL, J.L. BOURGADE, J.L LERAY, CEA — The National Ignition Facility (NIF) and the Laser Megajoule Facility (LMJ) are currently under construction in the U.S. and France, respectively. Ignited targets at these facilities are anticipated to produce up to 10^{19} DT neutrons. For approximately 500 ns after ignition, the NIF and LMJ target diagnostics and control systems will work under extremely harsh radiation conditions. In particular, neutron-induced signals in cables can compromise or destroy diagnostic instruments and control systems. Recent results of neutron-induced signal measurements at 30 kJ in different cables at the 60-beam OMEGA Laser Facility will be reported. Based on these results, specific recommendations on cable selection for the NIF and LMJ will be given. Neutron-background mitigation techniques in the NIF neutron time-of-flight diagnostics will be presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under the Cooperative Agreement No. DE-FC52-92SF19460.

10:42AM GO6.00007 EMP Measurements on the Omega Laser System at LLE , ZAHEER ALI, National Security Technologies, VLADIMIR GLEBOV, WADE BITTLE, CHRISTIAN STOECKL, GREG PIEN, THOMAS HINTERMANN, MARK LABUZETA, TIM DUFFY, CRAIG SANGSTER, University of Rochester, ALAN THROOP, DAVE EDER, JOE KINBROUGH, CHARLIE BROWN, LLNL, JOEL RAIMBOURG, CEA, France — We present the result of Electromagnetic Pulse measurements on the 30kJ, 60-beam, OMEGA laser system at the University of Rochester Laboratory for Laser Energetics. The suite of EMP probes includes free field electric and magnetic field sensors located internal and external to the OMEGA target chamber (1.5-2.3 m from target chamber center range). Measurements were taken under typical shot conditions for OMEGA and include variations in drive intensity, target size and mass and with neutron yields varying from zero to 1E13. Correlations of the EMP measurements with shot conditions will be presented. Such correlations are expected to form part of the basis for predictive EMP models on the National Ignition Facility. This work was supported by the U.S. DOE Office of Inertial Confinement Fusion cooperative agreement DE-FC52-92SF19460, NNSA Nevada Operations, contract DE-AC52-06NA25946 and by the University of California, LLNL, contract W-7405-Eng-48.

10:54AM GO6.00008 First Tests on OMEGA of a Bubble Chamber for Neutron Detection , M.C. GHILEA, D.D. MEYERHOFER, T.C. SANGSTER, D.J. LONOBILE, A. DILLENBECK, Laboratory for Laser Energetics, U. of Rochester, R.A. LERCHE, LLNL, L. DISDIER, CEA — To provide additional options for imaging at NIF, a high-resolution, reduced-line-of-sight detector was developed and tested at LLE. The detector is based on a high-pressure freon, 115-bubble chamber with an expansion mechanism controlled by a linear motor. A CCD camera is used to photograph the bubbles in parallel, monochromatic light, while a Schlieren disk is used to enhance the contrast of the image. With bubble diameters in the range of 100 μm, the achieved spatial resolution is significantly better than more-conventional pixilated arrays. The higher spatial resolution can be utilized to significantly shorten the neutron flight path. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

11:06AM GO6.00009 First Measurements of Neutron Spectra using the Magnetic Recoil Spectrometer (MRS) at OMEGA , J.A. FRENJE, D. CASEY, C.K. LI, J. RYGG, F.H. SEGUIN, R.D. PETRASSO, MIT PSFC, V.YU. GLEBOV, D.D. MEYERHOFER, T.C. SANGSTER, UR LLE, K. FLETCHER, SUNY GENESEO — A new type of neutron spectrometer, a Magnetic Recoil Spectrometer (MRS), is being implemented at OMEGA for measurements of the scattered-DT-neutron spectrum, from which ρR can be inferred. Implementing an MRS at OMEGA is important for several reasons. First, it allows comprehensive tests of the different MRS parameters. Second, ρR of cryogenic DT implosions can be inferred from both the MRS and charged-particle spectrometry for moderate ρR implosions (ρR<200 mg/cm^2); this allows for a definitive check of the MRS. Third, as there is no other way to determine ρR when it exceeds 200 mg/cm^2, the MRS will bring a required diagnostic to the OMEGA cryogenic program. Fourth, the experience with MRS implementation and resulting neutron data at OMEGA will enable us to implement an optimal MRS for the NIF. The results from the first MRS measurements performed at OMEGA are presented. This work was supported in part by the U.S. DOE (Grant No. DE-FG03-03SF22691), LLE (subcontract Grant No. 412160-001G), LLNL (subcontract Grant No. B504974).

11:18AM GO6.00010 Multiview observation and analysis of OMEGA direct-drive implosion cores[1] , T. NAGAYAMA, R.C. MANCINI, University of Nevada, Reno, L.A. WELSER-SHERRILL, Los Alamos National Laboratory, R. TOMMASINI, J.A. KOCH, Lawrence Livermore National Laboratory, J. DELETTREZ, S. REGAN, V. SMALYUK, Laboratory for Laser Energetics, I. GOLOVKIN, Prism Computational Sciences — We discuss the observation and data analysis of OMEGA direct-drive implosion cores based on data recorded with three identical multi-monochromatic x-ray imagers. These instruments observed the implosion core along three quasi-orthogonal lines-of-sight, and recorded gated images of the core. The targets were plastic shells filled with deuterium gas and a tracer amount of argon for diagnostic purposes. Core imaging was based on argon Lyα, Heβ and Lyβ line emission. The data analysis rely on detailed spectral models that take into account non-equilibrium atomic kinetics, Stark broadened line shapes, and radiation transport calculations and a search and reconstruction technique based on a novel application of Pareto genetic algorithms to plasma spectroscopy. The spectroscopic analysis yields the spatial profiles of temperature and density in the core at the collapse of the implosion.

[1]This work is supported by DOE/NLUF Grant DE-FG52-07NA28062, LLNL.

11:30AM GO6.00011 X-ray Thomson scattering on compressed Be plasmas[1] , HAE JA LEE, Physics Department, University of California, Berkeley, CA 94720-7300, PAUL NEUMAYER, OTTO LANDEN, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, ROGER FALCONE, Physics Department, University of California, Berkeley, CA 94720-7300, SIEGFRIED GLENZER, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550 — X-ray Thomson scattering measurements have provided much insight into characterization of dense plasmas such as in determining electron temperature, density, and ionization state [1]. We performed spectrally resolved 6 keV x-ray scattering on laser shock compressed Be plasmas in both the non-collective and collective forward scattering regime at the Omega laser facility. From the forward scattering geometry, we have measured a plasmon peak whose frequency is sensitive to the electron density. We will present first data that indicate a density of n_e=8$\times$10^{23}/cc can be reached for a pressure of 10-15 Mbar.
[1] S. H. Glenzer *et al.*, Phys. Rev. Lett. **98**, 065002 (2007); Phys. Rev. Lett. **90**, 175002 (2003). G. Gregori *et al.*, Phys. Plasmas **11**, 2754 (2004).

[1]Work performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

11:42AM GO6.00012 Low-Aberration Diffraction Mirror to Focus X-Rays , ACHIM SEIFTER, DAMIAN SWIFT, Los Alamos National Laboratory, JAMES HAWRELIAK, Lawrence Livermore National Laboratory — Radiography of laser-driven implosions is important for the development of inertial confinement fusion, and it is challenging to obtain adequate diagnostic radiographs of the compression of the fuel capsule. X-ray imaging, through the use of x-ray mirrors, can potentially increase the resolution and accuracy of radiographs, for instance by allowing radiography at locally normal incidence through an imploding spherical capsule. Mirrors for kilovolt x-rays usually work through crystal diffraction. Focusing mirrors have been demonstrated using planar crystals, bent to form a toroidal or spherical surface. We show that the correct profile for a focusing diffraction mirror requires the diffracting planes to change orientation with respect to the surface of the mirror, and suggest how such a bent crystal could be formed.

11:54AM GO6.00013 Characterization of High-Current Relativistic Electron Beam Transport Through Solid-Density Matter Using High-Resolution Imaging of Coherent Transition Radiation , M. STORM, J. MYATT, C. STOECKL, Laboratory for Laser Energetics, U. of Rochester — A diagnostic has been developed to measure the emission of coherent transition radiation produced by relativistic electrons emerging from the rear side of laser-illuminated targets. Experiments have been conducted on the Multi-Terawatt (MTW) Laser Facility at the University of Rochester's Laboratory for Laser Energetics. The MTW laser is capable of producing 10-J, 500-fs pulses of 1053-nm-wavelength radiation, which are focused using an $f/2.5$, off-axis parabolic mirror to an intensity in excess of 10^{19} W cm^{-2}. The initial experimental campaign used Al, Fe, Cu, Au, and CH foils of varying thickness, which were shot with varying laser energy. High-resolution images of the rear-side emission show evidence of both electron-beam filamentation and electron-beam annular propagation. In this talk we will present the most recently acquired data and provide a brief description of the diagnostic characteristics and capabilities. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

12:06PM GO6.00014 Quasi-DC Terahertz Electrical Conductivity Measurements of Dense Aluminum Plasma , GEORGE RODRIGUEZ, BALAKISHORE YELLAMPALLE, JAMES GLOWNIA, ANTOINETTE TAYLOR, KI-YONG KIM, Los Alamos National Laboratory — We report on our investigation of electrical transport in ultrashort laser-heated aluminum. By measuring the complex electrical conductivity at terahertz (THz = 10^{12} Hz) frequencies, we explore the dependence of electrical transport across the material phase transition from the cold solid to the dense plasma state. Using optical-pump, terahertz-probe spectroscopy, we measure the phase shifts and absorption of terahertz probe pulses that are reflected from the warm (0.1$\sim$3 eV) dense plasma. To characterize the THz field, we develop and use a single-shot, high temporal-resolution THz diagnostic capable of measuring free-space electromagnetic pulse fields in time and space. In contrast to the previous measurements of conductivities at optical frequencies, our THz non-contact probe method can directly measure quasi-DC electrical conductivities, providing insight into the transport nature of warm dense matter without dependence on conductivity models for extrapolation. Full hydrodynamic laser-foil calculations and THz Helmholtz wave equation calculations of the THz probe field show that deep penetration across the plasma gradient and into the dense solid is achieved with the THz probe. The technique demonstrates a new promising ultrafast time-resolved diagnostic capability for extracting conductivity transport.

12:18PM GO6.00015 Short pulse laser coupling efficiency to hot electrons for fast-ignition studies.[1] , A.G. MACPHEE, C.D. CHEN[2], D. HEY[3], I. JOVANOVIC, M.H. KEY, T.W. PHILLIPS, A.J. MACKINNON, Lawrence Livermore National Laboratory, Livermore CA 94550, R. CLARKE, CCLRC Rutherford Appleton Laboratory, Oxfordshire, UK, K. AKLI, D. OFFERMANN, A. LINK, V. OVCHINNIKOV, L. VAN WOERKOM, R. FREEMAN, College of Mathematical and Physical Sciences, The Ohio State University, Columbus, OH, J. PASLEY, M. WEI, T.Y. MA, J. KING, F.N. BEG, Department of Mechanical and Aerospace Engineering, University of California-San Diego, La Jolla, CA, R.B. STEPHENS, General Atomics, San Diego, CA — Experiments were performed at the Titan laser facility at LLNL to study energy coupling efficiency to hot electrons as a function of irradiation conditions and target geometry. Hot electron spectra from cone and slab targets are compared and correlation with their K shell emission spectra is examined.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48

[2]and Plasma Science Fusion Center, Massachusetts Institute of Technology, Cambridge, MA

[3]and University of California Davis, Dept. of Applied Sciences, Davis, CA

Tuesday, November 13, 2007 9:30AM - 12:18PM –

Session GO7 Laser Driven Electron and Ion Acceleration Rosen Centre Hotel Salon 7/8

9:30AM GO7.00001 Experimental Demonstration of 1 GeV Energy Gain and Stable Self Trapping in a Laser Wakefield Accelerator[1] , D. PANASENKO, A.J. GONSALVES, K. NAKAMURA, C. TOTH, C.G.R. GEDDES, E. CORMIER-MICHEL, C.B. SCHROEDER, E. ESAREY, W.P. LEEMANS, LBNL, S.M. HOOKER, Oxford, J. CARY, D. BRUHWILER, Tech-X — GeV-class electron accelerators have broad applications, including synchrotron facilities, free electron lasers, and high-energy physics (HEP). Laser-wakefield accelerators (LWFAs) may reduce cost and size of such accelerators (and push the HEP energy frontier), since LWFAs sustain electric fields of hundreds of GV/m, thousands of times those achievable in RF accelerators. Results will be presented on production of GeV-class beams using LWFAs*. Laser pulses with peak power ranging from 10-40TW were guided in gas-filled capillary discharge waveguides of length 15mm and 33mm, allowing the production of high-quality electron beams with energy up to 1 GeV. Stable self trapping and acceleration of beams to 500 MeV with few percent energy spread was also demonstrated. Electron beam characteristics and laser guiding, and their dependence on laser and plasma parameters will be discussed and compared to simulations. *Leemans et al., Nature Physics, 2006

[1]Work supported by DOE grant DE-AC02-05CH11231.

9:42AM GO7.00002 Stable electron bunches with low absolute momentum spread using plasma down ramp injection in a laser wakefield accelerator[1] , C.G.R. GEDDES, K. NAKAMURA, C. TOTH, E. ESAREY, C.B. SCHROEDER, W.P. LEEMANS, LBNL, E. CORMIER-MICHEL, UNR, J. CARY, D. BRUHWILER, Tech-X — Control of particle trapping in a laser wakefield accelerator using plasma density gradients produced stable electron bunches at momenta near 1 MeV/c and with 170 keV/c FWHM momentum spread, 20 keV/c RMS central momentum variation, and repeatable charge and pointing. A 10 TW laser pulse was focused near the downstream edge of a mm-long hydrogen gas jet so that plasma density near focus decreased in the laser propagation direction. Particle simulations indicate the gradient slowed wake phase velocity resulting in stable trapping. Simulations and transition radiation experiments indicate the bunches are ultrafast. Simulations further show that the bunches can be post accelerated in plasma wakes, potentially producing stable multi-GeV beams with greatly reduced momentum spread.

[1]Work supported by DOE grant DE-AC02-05CH11231, others, and using NERSC and incite.

9:54AM GO7.00003 Observation of large-angle quasi-monoenergetic electrons from a laser wakefield[1] , DMITRI KAGANOVICH[2], DANIEL GORDON, ANTONIO TING, NATALIE MILIOUTINA[3], PHILLIP SPRANGLE, Plasma Physics Division, Naval Research Laboratory, Washington, DC 20375 — A relativistically intense laser pulse is focused into a gas jet and quasi-monoenergetic electrons emitted at a 37 degree angle with respect to the laser axis are observed. The average energy of the electrons was between 1 and 2 MeV and the total accelerated charge was about 1 nC emitted into a 10 degree cone angle. The electron characteristics were sensitive to plasma density. The results are compared with three dimensional particle-in-cell simulations. This electron acceleration mechanism might be useful as a source of injection electrons in a laser wakefield accelerator.

[1]Supported by the Department of Energy and Office of Naval Research

[2]LET Corporation, Washington DC

[3]NRL Science and Engineering Apprentice Program

10:06AM GO7.00004 Electron Acceleration in Guiding and Non-Guiding Structures , C. KAMPERIDIS, S.P.D. MANGLES, S. KNEIP, K. KRUSHELNICK, Z. NAJMUDIN, Imperial College London, UK, T.P. ROWLANDS-REES, A.J. GONZALVES, S.M. HOOKER, University of Oxford, UK, E. BRUNETTI, J. GALLACHER, D.A. JAROSZYNKSI, University of Strathclyde, UK, C.D.M. MURPHY, P.A. NORREYS, Rutherford Appleton Laboratory, UK, F. BUDDE, Friedrich-Schiller Jena, Germany — We make a direct comparison of recent experimental results on laser wakefield acceleration, when the electrons are produced and accelerated in optically guiding and non-guiding plasma structures. In these experiments, ∼10TW laser pulses were guided through plasma channels of up to 50mm long, created either by external means (capillary channel formation) or by relativistic self-focusing of the laser pulse itself. Quasimonoenergetic electron beams were generated with energies up to 200MeV and energy spreads of a few %. High resolution, large scale 2D PIC simulations suggest that although the laser pulse evolution and injection process is similar, the final acceleration results differ from one case to the other, depending on background plasma density and whether or not a preformed guiding channel is used.

10:18AM GO7.00005 Direct Acceleration of Electrons in a Corrugated Plasma Waveguide , JOHN PALASTRO, ANDREW YORK, THOMAS ANTONSEN, HOWARD MILCHBERG, University of Maryland — Direct laser acceleration of electrons provides a low power tabletop alternative to laser wakefield accelerators. Until recently, however, direct acceleration has been limited by diffraction, phase matching, and material damage thresholds. The development of the corrugated plasma channel has simultaneously removed all of these limiting factors and promises to allow direct acceleration of electrons over many centimeters at high gradients using femtosecond lasers. We present a simple analytic model of laser propagation in a corrugated plasma channel and examine the laser-electron beam interaction. Simulations show accelerating gradients of several hundred MeV/cm for laser powers much lower than required by standard laser wakefield schemes.

10:30AM GO7.00006 Evolution of Relativistic Plasma-Wave front in LWFA[1] , FANG FANG, CHRISTOPHER CLAYTON, KENNETH MARSH, JOSEPH RALPH, ARTHUR PAK, UCLA, NELSON LOPES, Universidade Técnica de Lisboa, CHANDRASHEKHAR JOSHI, UCLA — In a laser wake field accelerator experiment where the length of the pump laser pulse is several plasma period long, the leading edge of the laser pulse undergoes frequency downshifting as the laser energy is transferred to the wake. Therefore, after some propagation distance, the group velocity of the leading edge of the pump pulse, and therefore of the driven electron plasma wave, will slow down. This can have implications for the dephasing length of the accelerated electrons and therefore needs to be understood experimentally. We have carried out an experimental investigation where we have measured the velocity v_f of the 'wave-front' of the plasma wave driven by a nominally 50fs (FWHM), intense (a0 $\sim$ 1), 0.8μm laser pulse. To determine the speed of the wave front, time- and space-resolved reflectometry, interferometry, and Thomson scattering were used. Although low density data ($n_e \sim 1.3 * 10^{19}$cm^{-3}) showed no significant changes in v_f over 1.5mm (and no accelerated electrons), high-density data ($n_e \sim 5*10^{19}$cm^{-3}) shows accelerated electrons and an approximately 5% drop in v_f after a propagation distance of about 800μm.

[1]This work is supported by NNSA grant no. DE-FG-03NA00138 and DOE grant no DE-FG02-92ER40727

10:42AM GO7.00007 Laser acceleration with imploding plastic cylinder shell , KIMINORI KONDO, Graduate School of Engineering, Osaka University, NOBUHIKO NAKANII, Osaka Univ., YOSHITAKA MORI, GPI, EISUKE MIURA, AIST, KAZUKI TSUJI, KAZUYA KIMURA, KAZUO TAKEDA, SYUJI FUKUMOCHI, Osaka Univ., MAMORU KASHIHARA, Osaka Univ, TSUYOSHI TANIMOTOI, HIROTAKA NAKAMURA, TAKAHIKO ISHIKURA, MOTONOBU TAMPO, RYOSUKE KODAMA, Osaka Univ., YONEYOSHI KITAGAWA, GPI, KUNIOKI MIMA, KAZUO TANAKA, Osaka Univ. — High energy electrons over 500 MeV were generated with Gekko XII laase system and PW laser system in ILE (Institute of Laser Engineering, Osaka University). For making a hollow plasma tube to take a long propagation distance, a plastic cylinder shell was imploded by 6 beams of Gekko XII laser system. The relativistic optical pulse yielded from PW laser system propagated through 3 mm long plasma tube with making a self-modulated laser wakefield. Thermal electrons were self-injected to this acceleration field formed by the electron plasma wave, and were accelerated to the relativistic speed. The kinetic energy distribution of these electrons was measured by the calibrated electron spectrometer (ESM). The observed accelerated electrons are over 500 MeV with a broad spectrum and reach up to800 MeV.

10:54AM GO7.00008 Photon acceleration and modulational instability during wakefield excitation using long laser pulses , RAOUL TRINES, CHRISTOPHER MURPHY, ROBERT BINGHAM, KATHRYN LANCASTER, OLEG CHEKHLOV, PETER NORREYS, STFC Rutherford Appleton Laboratory, JOSE TITO MENDONCA, LUIS SILVA, Instituto Superior Tecnico, Lisbon, Portugal, STUART MANGLES, CHRISTOS KAMPERIDIS, ALEXANDER THOMAS, KARL KRUSHELNICK, ZULFIKAR NAJMUDIN, Blackett Laboratory, Imperial College, London, UK — Recent laser-wakefield experiments on the Astra laser at RAL using laser pulses that are several times longer than the wakefield period have yielded transmission spectra that exhibit a series of secondary peaks flanking the main laser peak. It has been found that these peaks are too closely spaced to be the result of Raman instabilities; instead, photon acceleration of the laser's photons in the wakefield has been proposed as the likely origin of the secondary peaks. In this paper, we present the results of recent Astra experiments in which a laser pulse of 50-200 fs containing 300-600 mJ was focused on a helium gas jet on a 25 micron focal spot. The observed transmission spectra have been modelled using a dedicated photon-kinetic numerical code. The origin of various spectral characteristics will be explained in terms of photon acceleration, and the feasibility of using this effect as a wakefield diagnostic will be discussed.

11:06AM GO7.00009 Control of laser-accelerated ions: Recent advances and preliminary results from the new Trident 250-TW laser[1] , B. MANUEL HEGELICH, BRIAN J. ALBRIGHT, LIN YIN, KIRK A. FLIPPO, D. CORT GAUTIER, SAMUEL LETZRING, LANL, ROLAND SCHULZE, MARK SCHMITT, JUAN C. FERNANDEZ, LANL, LANL TEAM — Advanced target design, treatment and characterization enable progress in laser-driven ion acceleration. We demonstrate spectral shaping and mono-energetic features from in-situ formed source layers on different substrate materials. Advanced targets and experimental techniques allow control of the properties of laser accelerated ion beams, which is of importance to future applications like Ion Fast Ignition (IFI), WDM research and others. We will also present preliminary results from the new 250-TW Trident laser system that will allow the extrapolation of scaling laws similar to those derived for proton acceleration.

[1]Work performed under the auspices of the U. S. Dept. of Energy by the Los Alamos National Security, LLC, Los Alamos National Laboratory.

11:18AM GO7.00010 Proton acceleration: new developments for focusing and energy selection, and applications in plasma physics , P. AUDEBERT, Laboratoire pour l'Utilisation des Lasers Intenses — In the last few years, intense research has been conducted on laser-accelerated ion sources and their applications. These sources have exceptional properties, i.e. high brightness and high spectral cut-off, high directionality and laminarity, short burst duration. We have shown that for proton energies >10 MeV, the transverse and longitudinal emittance are respectively <0.004 mm-mrad and $<10^{-4}$ eV-s, i.e. at least 100-fold and may be as much as 10^4-fold better than conventional accelerators beams. Thanks to these properties, these sources allow for example point-projection radiography with unprecedented resolution. We will show example of such time and space-resolved radiography of fast evolving fields, either of associated with the expansion of a plasma in vacuum [*] or with the propagation of a ICF-relevant laser beam in an underdense plasma. These proton sources also open new opportunities for ion beam generation and control, and could stimulate development of compact ion accelerators for many applications.

11:30AM GO7.00011 In-situ target preparation and characterization for mono-energetic laser driven ion sources , CORT GAUTIER, Los Alamos National Laboratory, KIRK FLIPPO, ROLAND SCHULZE, BRIAN ALBRIGHT, LIN YIN, JUAN FERNANDEZ, MANUEL HEGELICH, LANL — Recent advances in laser-driven ion acceleration demonstrated the direct production of mono-energetic ion pulses from ultrahigh intensity lasers. A key component responsible for this mechanism is a highly ordered, 10A source layer on a high-Z substrate. Due to the typical vacuum conditions in ultrahigh power laser target chambers, in-situ formation and characterization is a prerequisite to control and manipulate those ion pulses and achieve lower shot-to-shot fluctuations. We present results of an experimental investigation of the in-situ formation and characterization of this ion source layer. Using X-ray photoelectron spectroscopy (XPS) we observed a temperature dependence of the formation of a thin carbon layer on Pd and Pt substrates in a controlled hydrocarbon environment. These results validate our hypothesis for the mechanisms responsible for laser driven mono-energetic ion production and will be compared to PIC simulation and measurements of mono-energetic ions from Pd and Pt targets shot at intensities of I$\sim 10^{19}$ W/cm^2 at the Trident short pulse laser facility.

11:42AM GO7.00012 Generation of Monoenergetic proton beams from double-layer foils by flat-top laser pulses.. , STEPAN BULANOV, VLADIMIR CHVYKOV, FOCUS and CUOS, University of Michigan, ANDREI BRANTOV, VALERY BYCHENKOV, Phys. Inst., Russian Academy of Sciences, GALINA KALINCHENKO, TAKESHI MATSUOKA, PASCAL ROUSSEAU, STEPHEN REED, VIKTOR YANOVSKY, FOCUS and CUOS, University of Michigan, DALE LITZENBERG, Dep. Rad. Oncology, University of Michigan, KARL KRUSHELNICK, ANATOLY MAKSIMCHUK, FOCUS and CUOS, University of Michigan — The effect of laser pulse shaping on the proton acceleration by a tightly focused pulse from ultra-thin double layer solid targets in the regime of Directed Coulomb Explosion (DCE) is discussed. The theoretical model and the results of PIC simulations of this regime are presented. In DCE regime the foil is first accelerated by the radiation pressure and then experiences a Coulomb explosion thus generating a moving charge separation longitudinal field that effectively accelerates second layer protons. The utilization of the pulse shaping, namely the use of flat-top pulses, leads to a significant enhancement of the efficiency of proton acceleration due to the increase of the longitudinal field.

11:54AM GO7.00013 Two Stage Proton Acceleration from Ultrathin Foils via High Intensity, High Contrast Laser Pulses[1]

, S.A. REED, T. MATSUOKA, S.S. BULANOV, V. CHVYKOV, FOCUS Center and CUOS, University of Michigan, A. BRANTOV, V. BYCHENKOV, Lebedev Physics Institute, G. KALINCHENKO, C. MCGUFFEY, P. ROUSSEAU, V. YANOVSKY, FOCUS Center and CUOS, University of Michigan, D. LITZENBERG, Dept of Radiation Oncology, University of Michigan, K. KRUSHELNICK, A. MAKSIMCHUK, FOCUS Center and CUOS, University of Michigan — Laser driven proton acceleration from submicron targets using high intensity ($4\text{x}10^{20}$W/cm^2), high contrast (10^{-11}) laser pulses has been investigated. PIC simulations show two distinct acceleration stages: first, a charge separation at the target front due to the laser's ponderomotive force, and second, the rear TNSA mechanism. The two acceleration stages were experimentally distinguished through target selection. The maximum proton energy observed for hydrogen containing targets (CH) was two times higher than for non-hydrogen containing targets (Si_3N_4). For H containing targets the protons are accelerated first by the pondermotive potential, propagate through the target and receive additional acceleration from the rear sheath, whereas Si_3N_4only receives TNSA thus yielding lower proton energy.

[1]Supportedby NSF grant PHY-0114336, NIH grant R21CA120262-01

12:06PM GO7.00014 Collimated High-Quality Proton Beam Generation in Laser Tailored-Target Interaction[1]

, S. KAWATA, M. NAKAMURA, R. SONOBE, N. ONUMA, Y. NODERA, S. MIYAZAKI, T. KIKUCHI, Utsunomiya University, Japan, Q. KONG, Fudan University — A high-quality collimated proton beam generation is demonstrated by using a tailored thin foil target. A robustness of a thin-foil tailored hole target is demonstrated by particle simulations in laser-produced proton generation. The tailored target has holes at the target rear surface. When an intense short pulse laser illuminates the thin foil target with the hole, transverse edge fields of an accelerated electron cloud and an ion cloud are shielded by a protuberant part of the hole so that the proton beam divergence is suppressed [1, 2]. This paper presents the robustness of the hole target against laser parameter changes in a laser spot size and in a laser pulse length, against a contaminated proton source layer and against a laser alignment error. The 2.5-dimensional PIC (particle-in-cell) simulations also present that a multiple-hole target is robust against a laser alignment error and a target positioning error. The multi-hole target may serve a robust target for practical uses to produce a collimated proton beam. [1] R. Sonobe, et al., Phys. Plasmas, 12 (2005) 073104. [2] M. Nakamura, et al., J. Appl. Phys., 101 (2007) 113305.

[1]This work was partly supported by JSPS, MEXT, Center for Optical Researcha and Education (CORE), Utsunomiya Univ., and ILE.

9:30AM - 9:30AM –

Session GP8 Poster Session III: Turbulence, Transport, and NL Processes; Fast Ignition and Laser-Plasma Interactions; Divertors, Edge Physics and Fueling; MHD Theory, Heating and Current Drive; Simulation: MHD; Optimal Helicon Source Performance Rosen Centre Hotel Grand Ballroom, 9:30am - 12:30pm

GP8.00001 TURBULENCE, TRANSPORT, AND NONLINEAR PROCESSES –

GP8.00002 Fundamental Scalings of Zonal Flows in a Basic Plasma Physics Experiment[1]

, VLADIMIR SOKOLOV, XIAO WEI, AMIYA K. SEN, Columbia University — A basic physics experimental study of zonal flows (ZF) associated with ITG (ion temperature gradient) drift modes has been performed in the Columbia Linear Machine (CLM) and ZF has been definitively identified [1]. However, in contrast to most tokamak experiments, the stabilizing effect of ZF shear to ITG appears to be small in CLM. We now report on the study of important scaling behavior of ZF. First and most importantly, we report on the collisional damping scaling of ZF, which is considered to be its saturation mechanism [2]. By varying the sum of ion-ion and ion-neutral collision frequency over nearly half an order of magnitude, we find no change in the amplitude of ZF. Secondly, we study the scaling of ZF amplitude with ITG amplitude via increasing ITG drive though η_i, as well as feedback (stabilizing / destabilizing). We have observed markedly different scaling near and far above marginal stability.
[1] V. Sokolov, X. Wei, A.K. Sen and K. Avinash, *Plasma Phys.Controlled Fusion 48, S111 (2006).*
[2] *P.H. Diamond, S.-I. Itoh, K.Itoh and T.S. Hahm, Plasma Phys.Controlled Fusion 47, R35 (2005).*

[1]This research was supported by U.S. Department of Energy Grant No. DE-FG02-98ER-54464.

GP8.00003 A Basic Experiment on the Production and Identification of ETG Modes[1]

, XIAO WEI, VLADIMIR SOKOLOV, AMIYA K. SEN, Columbia University — One of the strongest candidates for the anomalous electron energy transport is believed to be electron temperature gradient (ETG) mode [1, 2]. However, the high frequency (few MHz) and short wave length ($k_\perp \rho_e < 1$) make the direct observation of ETG modes difficult in experiments. Using a DC bias heating scheme of the core plasma, we are able to produce the drive parameter $\eta_e = dln T_e/dlnn$ from 1 to 6 ($T_e \sim 20eV$ in the center and $\sim 1eV$ on the edge) in Columbia Linear Machine (CLM). A high frequency mode at $\sim 2MHz$has been observed. Its azimuthal wave number in $m \sim 30$ has been measured. These values are consistent with the results of a simple kinetic dispersion relation on appropriate $\vec{E_0} \times \vec{B}$ Doppler shift. The problem of the measurement of the small parallel wave number with the large azimuthal wave number has been resolved by a novel diagnostic method. The scaling of ETG fluctuation level versus η_e, as well as the radial structure of the mode will be reported.
[1] W. Dorland et al., *Phys. Rev. Lett. 85, 5579 (2000).*
[2] *R.E. Waltz, J. Candy and M. Fahey, Phys. Plasmas 14, 056116 (2007).*

[1]This research was supported by U.S. Department of Energy Grant No. DE-FG02-98ER-54464.

GP8.00004 Edge turbulence scaling in RFX-mod with GPI diagnostic

, PAOLO SCARIN, MATTEO AGOSTINI, ROBERTO CAVAZZANA, GIANLUIGI SERIANNI, Consorzio RFX — In the Reversed Field Pinch eXperiment RFX-mod (R=2 m, a=0.46 m) a Gas Puffing Imaging (GPI) diagnostic is routinely used to investigate the dynamical structure of plasma edge turbulence in different plasma conditions. The GPI system (32 optical lines of sight) measures radiation emitted from puffed gas on a plane normal to the local magnetic field. Such diagnostic allows the investigations of edge plasma properties with high time and space resolution even at high plasma current and through the entire plasma pulse. The characterization of edge turbulence has been carried out in terms of power spectrum, toroidal velocity v_ϕ of emission fluctuations, linear density and toroidal width of emission structures. The packing fraction f_p of emission intermittent structures has been estimated as the total area occupied by emission blobs in a plane perpendicular to magnetic field. The scaling with normalized Greenwald density $n/n_G$of v_ϕ, f_p, linear density and toroidal width of emission structures and decay index of the power spectrum are reported. A comparison at different density regimes of the diffusivity D_p of the plasma trapped in coherent structures is proposed and a decrease of about a factor of 2 results between low and high n/n_G values.

GP8.00005 Self Consistent Computations of the Tokamak Edge with Nonlocal Electromagnetic Gyrofluid Equations , BRUCE SCOTT, Max-Planck-IPP, Euratom Association, Garching, Germany — Turbulence in a nonlocal tokamak edge setting is computed using a recently derived gyrofluid model based on the fully nonlinear electromagnetic gyrokinetic equation. Six moments are carried for each species. Energy content in velocities and specific heat fluxes parallel to the magnetic field is allowed to be order unity. The dissipation model allows for the neoclassical equilibrium for flows, currents, and heat fluxes. Transition from SOL to edge to core is contained within a single computation. The edge layer is run to transport equilibrium. Simple sheath dissipation and neutral source models are used in the SOL. This represents an attempt to clarify whether edge/core nonlocality over only a few centimetres is sufficient for a first principles capture of the H-mode and pedestal formation. Further complexity and necessary generalisations will be discussed at the meeting.

GP8.00006 Relaxation of weights in a δf code[1] , ALLEN BOOZER, Columbia University — The weight of particle i in a δf particle following code obeys $dw_i/dt = \dot{W}(\vec{x}_i, \vec{p}_i)$. The phase space location of the particle is $(\vec{x}_i, \vec{p}_i)$, and $\dot{W}$ is given by derivatives of a background Maxwellian. The weights w_i tend to increase without limit. When the w_i become sufficiently large the approximations used in δf codes become invalid. The long-term increase in w_i is unphysical since a particle should loose its history within a collision time. The addition of a term to the weight evolution equation solves the problem, $dw_i/dt = \dot{W} - \nu_w w_i$. If the constant ν_w is chosen to be comparable to, or smaller than, the collision frequency it should have no effect on physically correct outputs of the code, but should keeps the weights at a low amplitude forever. In order to conserve particles, the background Maxwellian must be modified so its density obeys $dn(\psi)/dt = \nu_w n \sum_i w_i f_i / \sum_i f_i$, where the sum is over an annular radial region. Similar changes in flow and temperature of the background Maxwellian are required to conserve momentum, and energy.

[1]Supported under U.S. Department of Energy grant DE-FG02-03E.

GP8.00007 Entropic Lattice Boltzmann Algorithms for Turbulence[1] , GEORGE VAHALA, William & Mary, JEFFREY YEPEZ, Air Force Research Lab., Hanscom Field, MIN SOE, Rogers State University, LINDA VAHALA, Old Dominion University, BRIAN KEATING, William & Mary, JONATHAN CARTER, NERSC, LBNL — For turbulent flows in non-trivial geometry, the scaling of CFD codes (now necessarily non-pseudo spectral) quickly saturate with the number of PEs. By projecting into a lattice kinetic phase space, the turbulent dynamics are simpler and much easier to solve since the underlying kinetic equation has only local algebraic nonlinearities in the macroscopic variables with simple linear kinetic advection. To achieve arbitrary high Reynolds number, a discrete H-theorem constraint is imposed on the collision operator resulting in an entropic lattice Boltzmann (ELB) algorithm that is unconditionally stable and scales almost perfectly with PE's on any supercomputer architecture. At this mesoscopic level, there are various kinetic lattices (ELB-27, ELB-19, ELB-15) which will recover the Navier-Stokes equation to leading order in the Chapman-Enskog asymptotics. We comment on the morphology of turbulence and its correlation to the rate of change of enstrophy as well as simulations on 1600^3 grids.

[1]work supported by DoE and AFOSR

GP8.00008 Nonlinear Excitation of Damped Eigenmodes in GYRO Microturbulence Simulations , DAVID HATCH, University of Wisconsin - Madison, PAUL TERRY, University of Wisconsin -Madison, BILL NEVINS, Lawrence Livermore National Laboratory — Recent work has demonstrated that linearly damped eigenmodes can be nonlinearly excited to levels that significantly affect saturated turbulent transport. This has been shown in reduced CTEM and ITG-like fluid models [1]. We analyze microturbulence data from GYRO to discover which if any of these effects exist in comprehensive simulations. It has long been noted that the spectrum for ITG-driven turbulence peaks at wavenumbers well below the fastest growing wavenumbers. In addition, the growth rate of the fastest growing ITG mode is positive well beyond the range of significant fluctuation amplitude. We examine the possibility of energy dissipation through linearly damped modes as an explanation for these phenomena. We bound damped eigenmode excitation from energetic considerations, given growth rate spectra and energy spectra. We examine cross correlations spectrally and compare to quasilinear values. Comparisons with simpler fluid models are also undertaken.
[1] P.W. Terry, D.A. Baver, and S. Gupta, Phys. Plasmas **13**, 022307 (2006)

GP8.00009 Exponential Frequency Spectrum in a Magnetized Plasma–UCLA , MEIXUAN SHI, DAVID PACE, JAMES MAGGS, GEORGE MORALES, UCLA — The frequency spectrum of density and temperature fluctuations associated with a controlled, electron temperature filament in a magnetized plasma is investigated. A hot, narrow electron-temperature structure is generated from injection of a small, low-voltage beam into the LAPD-U device. Fluctuations develop after an initial quiescent period dominated by classical electron heat transport. Coherent structures associated with drift-Alfven modes grow due to the electron temperature gradient, but eventually a broadband frequency spectrum emerges, which exhibits an exponential frequency dependence for frequencies less than a third of the ion cyclotron frequency. Similar spectra have been previously observed in totally different experimental situations, including in tokamak plasmas.. Using a variety of signal analysis techniques, it is found that the exponential frequency dependence arises from a series of individual, soliton-like pulses. The relationship of the width, occurrence-frequency and amplitude of individual pulses to the exponential spectral index is determined. The dependence of the formation and characteristics of the solitary pulses on heating power, and magnetic field is explored.

GP8.00010 Thermal Waves in a Magnetized Plasma , DAVID PACE, M. SHI, J.E. MAGGS, G.J. MORALES, UCLA — In recent years the topic of "thermal waves" has received considerable attention outside the plasma community. This peculiar phenomenon refers to the temperature fluctuations that arise when a system, described by a thermal diffusion equation, is subjected to an oscillating heat source. By measuring the propagation characteristics of the oscillatory temperature signals it is possible to determine the thermal conductivities of gases and solids to great precision. The present study uses observations of selfmodulated temperature fluctuations arising in a thermal filament produced by a small, low-voltage beam to study the behavior of thermal waves in a magnetized plasma. The beam is injected, at fixed voltage, into the large LAPD-U device and, in the absence of self-modulation, it creates a quiescent temperature filament 6 meters long and 0.5 cm diameter. When temperature modulations arise, axial and radial propagation of thermal waves are clearly detected. Comparison of the measured phase speeds to theoretical predictions, and to results of a transport code, show excellent agreement with the classical conductivities due to Coulomb collisions. This classical transport behavior has been independently verified in the absence of modulation. An assessment is made of the utility of a voltage-modulated beam source designed to diagnose the thermal conductivity of plasmas based on thermal waves.

GP8.00011 Basis function bispectral analysis in a cylindrical coordinate system , D.A. BAVER, P.W. TERRY, University of Wisconsin-Madison, G.R. TYNAN, S.H. MUELLER, University of California-San Diego — Bispectral analysis is a class of algorithms for inferring turbulence parameters using measured data to fit to a generic model equation. However, the model equations used in previous bispectral algorithms do not account for the geometry of actual plasma experiments. This can potentially produce spurious results, so an algorithm tailored to the geometry of a specific experiment is desirable. We present an algorithm adapted to the cylindrical coordinate system found in experiments such as CSDX. This algorithm uses an incomplete basis approximation for both linear and nonlinear terms. This approach is chosen because the linear eigenmodes cannot be known a priori since mode width depends on flow shear; the resulting coupling between assumed eigenmodes requires the calculation of an interaction matrix, which greatly increases data requirements. Applying a smoothness assumption reduces data requirements to acceptable levels, allowing the algorithm to operate on limited data sets. We will demonstrate tests of this algorithm on simulation data, and we will also apply the algorithm to experimental data from CSDX. Varying the model equations permits solutions for both single field and multiple field data, which can be compared to determine the importance of multifield effects. Work supported by USDOE.

GP8.00012 Investigation of electrostatic and magnetic structures at small scale in the edge region of RFX , ROBERTO CAVAZZANA, Consorzio RFX, MATTEO AGOSTINI, Dipartimento di Fisica - Universita di Padova, PAOLO SCARIN, GIANLUIGI SERIANNI, Consorzio RFX — A set of three three-axial high frequency magnetic pick-up coils has been recently added to the gas puffing imaging (GPI) diagnostic system installed on RFX. The fluctuations of He-alpha emission from the puffed gas cloud extend in the range above 10 kHz up to several hundred kHz and have been found to be mainly linked to density fluctuations associated to electrostatic structures moving in the plasma edge. The signals collected with the new magnetic probes show a strong correlation of these density fluctuations with magnetic fluctuations in the same frequency range. The spatio-temporal phase and amplitude relation between magnetic and emission signals will be investigated, aimed at identifying the principal instability driving the electrostatic turbulence in the edge RFP region.

GP8.00013 Nonlinear Dynamics of Fluctuations and Convective Blobs in the Presence of Sheared Flows in a Magnetized Laboratory Plasma[1] , L. YAN, M. GILMORE, C. WATTS, S. XIE, University of New Mexico — It has been observed that some instabilities can be triggered by localized flows, both azimuthally and axially. It also has been demonstrated that the presence of sheared flows at the plasma edge is strongly correlated to the reduction of low frequency instabilities and associated cross-field transport. To investigate the details of how those instabilities interact with plasma flows, experiments are being conducted in the HELCAT (HELicon-CAThode) linear device at UNM. HELCAT is a 4 m long device, with B < 0.22 T, and peak helicon-produced densities, n $\sim 10^{13}$ cm^{-3}. Sheared ExB flows, generated via biased concentric rings, are utilized to modify the flow profile. Fluctuations and flux are monitored with probe arrays, and flows, both azimuthal and axial, are measured by a Mach probe. It is found that drift waves are present when RF power exceeds a pressure-dependant threshold. Biasing can suppress the drift instability, while increased bias drives a new mode, believed to be Kelvin-Helmholtz. Parameters, such as RF power, gas pressure, bias voltage, and magnetic field, are investigated for their effects on plasma behavior. Experimental and analysis results will be presented.

[1]Work supported by the U.S. D.o.E. under grant no. DE-FG02-04ER54791.

GP8.00014 Observation of Chaos in a Magnetized Laboratory Plasma under the Influence of Variable Biasing[1] , S. XIE, C. WATTS, M. GILMORE, L. YAN, University of New Mexico — Ion saturation current fluctuation data from helicon plasmas in the linear HELCAT (HELicon-CAThode) device under positive biasing (with respect to the vacuum chamber wall) of a set of concentric rings is analyzed. HELCAT is 4 meters long, 0.5 meter in diameter, with dual plasma sources (RF Helicon and Ni-BaO thermionic cathode), helicon plasma peak density $\sim 10^{19}$ m^{-3}, and magnetic field up to 0.22T. Analysis shows that the helicon plasma is in a weakly turbulent state caused by drift waves before positive biasing of the rings. When the bias voltage is increased, drift waves start to be suppressed, finally disappearing when the bias voltage is around 12 volts ($\sim$ 3kTe/e). At suppression, a phase plot shows a simple attractor. As the bias is further increased, period doubling bifurcations are observed, and simultaneously the plasma enters a chaotic state with correlation dimension 2–3. At higher bias, the plasma develops a new, intermittent, instability, which is believed to be a Kelvin-Helmholtz mode, and a continued increase of the correlation dimension to values greater than 3.

[1]Work supported by the U.S. D.o.E. under Grant no. DE-FG02-04ER54791.

GP8.00015 On the Statistical Properties of the Turbulent Reynolds Stress , ZHENG YAN, GEORGE TYNAN, JONATHAN YU, CHRIS HOLLAND, STEFAN MULLER, MIN XU, Center For Energy Research — Statistical properties of the turbulent Reynolds stress has been studied on the CSDX linear device. The strongest power of the turbulent Reynolds stress is located near the maximal density gradient region, and the cross-phase between the turbulent radial and azimuthal velocity fields determines the shape and the amplitude of the Reynolds stress, and hence the shear flow generation. The PDF of the turbulent ion-saturation current shows that density bursts are born in the vicinity of the shear layer. Joint PDF between the turbulent ion-saturation current, turbulent radial and azimuthal velocity fields and Reynolds stress are computed, as well as the time-averaged vorticity fields, which allows the study of the relation between the formation of blobs of enhanced plasma density in the far edge region, the behavior of the Reynolds stress, its cross-phase and cross-coherence, generation of bursty radially going azimuthal momentum transport events, and the formation of the large-scale shear layer.

GP8.00016 Microturbulence, shear and burstiness in basic experimental plasmas , S.H. MULLER, C. HOLLAND, G.R. TYNAN, M. XU, Z. YAN, J.H. YU, UCSD Center for Energy Research, La Jolla, CA 92093, A. FASOLI, I. FURNO, B. LABIT, M. PODESTA, CRPP EPFL, 1015 Lausanne, Switzerland — We present basic experimental studies of the interplay between microturbulence, shear flow and plasma bursts. On the linear devices CSDX and LAPD, a shear layer (SL) is found to develop in the transition region between the core and edge plasma. Multi-tip Langmuir-probe (LP) measurements on CSDX support the idea that the effective Reynolds stress (RS) of microscopic fluctuations acts as a momentum transport mechanism, which sustains the shear layer. On LAPD, wall biasing is used to study the response of the RS-SL system to an external momentum source. Both on CSDX and on the toroidal device TORPEX, radial plasma bursts are observed to occur intermittently. In both cases, the bursts are found to originate from large wave crests of a dominant coherent mode that is subject to a background sheared flow. On TORPEX, the distortion of wave crests leading to the detachment of blobs is directly visualized using an 86-tip LP array. The dynamical and transport properties of these blobs are characterized quantitatively and striking similarities with tokamak observations are reported. These results suggest that gradient-driven drift turbulence can drive large-scale shear flows which, in turn, mediate the birth of bursty events.

GP8.00017 Experimental Study of Nonlinear Energy Transfer in Frequency Domain , MIN XU, CHRIS HOLLAND, STEFAN MULLER, GEORGE TYNAN, ZHENG YAN, JONATHAN YU, UCSD Center For Energy Research — The transfer of turbulent energy between different fluctuation scales is of great interest to obtain an understanding of the development of turbulence and formation of turbulent-driven shear flows in magnetized plasmas. Under some conditions, different spatial scales can generally be associated with different frequency scales, and thus the study of turbulent energy transfer in the frequency domain is also of interest. Based on the turbulent plasma continuity and momentum equations, the nonlinear internal and kinetic energy transfer terms can be explicitly measured in experiment. First attempt aimed at measuring these energy transfer terms have been carried out by using a 9-tip Langmuir probe array in the CSDX linear plasma device. Initial results from this work are reported in this poster.

GP8.00018 Fluctuations, turbulence and related transport in the TORPEX magnetised toroidal plasma , AMBROGIO FASOLI, AHMED DIALLO, IVO FURNO, DAVOUD IRAJI, BENOIT LABIT, GENNADY PLYUSHCHEV, FRANCESCA POLI, PAOLO RICCI, CHRISTIAN TEILER, CRPP-EPFL, Lausanne CH-1015, Switzerland, STEFAN MULLER, UCSD, CA92093, USA, MARIO PODESTA', UCI, CA92697, USA — Progress in understanding fluctuations, turbulence and related transport in magnetized plasmas is achieved in TORPEX via high-resolution measurements of plasma parameters and wave fields throughout the plasma cross-section. Electrostatic drift-interchange instabilities are characterized in terms of dispersion relation, driving mechanisms and development into turbulence. Measurements of density fluctuation time series across the plasma cross-section in a variety of plasma conditions reveal universal aspects such as a quadratic relation between skewness and kurtosis. Full spatio-temporal imaging of the electrostatic fluctuations is undertaken, using a multiple probe array or via conditional sampling of data obtained from movable probes. Blobs are observed to carry plasma from the core to the plasma edge. The blob generation and ejection are related to the a strongly sheared ExB flow. The blob effect on cross-field transport is investigated in details. Future research lines, such as active control of drift-interchange spectra using tunable antennas, optical turbulence imaging, and the study of the interaction of suprathermal ions with drift-interchange turbulence, will be discussed.

GP8.00019 Onsager Regression in phase-space resolved ion fluctuations.[1] , FRED SKIFF, University of Iowa — Onsager regression is the hypothesis that there is no difference between a fluctuation and a linear excitation. It implies that there is a connection between certain correlation functions and the linear response function. We explore this connection by comparing phase-space resolved correlation functions for ion fluctuations to linear response functions for the ion response. The data come from two-point correlation functions measured in a singly ionized Argon discharge plasma using laser-induced fluorescence. The experiments are performed in a plasma cylinder of density 10^9 cm^{-3} and a uniform magnetic field of 1kG. The LIF laser is aligned parallel to the magnetic field and two periscope detection systems are aligned to view points on the beam separated by a variable distance along the magnetic field. LIF measurements of fluctuations are not able to directly view the presence of particle discreteness because optical pumping and collisions make it improbable that there will be even one detected photon per metastable ion. Thus, all the cross-correlation results have to do with collective effects (modes). Nevertheless, there is a kinetic "free-streaming" part that is a significant part of the fluctuations. Although it is not at all clear that a linear theory should apply to these fluctuations because nonlinear correlations are evident in the bicoherence, and there should be trapped particle effects, we find that the kinetic component also can be described by an impulse response function

[1]Work supported by U.S. DOE grant DE-FG02-99ER54543

GP8.00020 Application of fractional diffusion to model perturbative transport experiments in JET , DIEGO DEL-CASTILLO-NEGRETE, Oak Ridge National Laboratory, PAOLA MANTICA, Istituto di Fisica del Plasma, Associazione Euratom-ENEA-CNR, Italy, VOLKER NAULIN, J. RASSMUSSEN, Association EURATOM - Risoe National Laboratory Technical University of Denmark, JET EFDA CONTRIBUTORS TEAM — Perturbative transport experiments follow the transient response of the plasma to externally applied small perturbations, e.g. plasma edge cooling and heating power modulation. These experiments provide time dependent information that can be used for testing models. JET experiments show an asymmetry between the relatively slow propagation of ICRH power modulation perturbations and the fast propagation of edge cold pulses [1]. Previous attempts to model these experiments have not been successful. In particular, while local models are able to reproduce the modulation data, they underestimate the speed of the pulses. Here we show that a non-local transport model based on the use of fractional diffusion operators [2] is able to describe the JET experiments. The model reproduces the amplitude and phase profiles of the modulation data and, most importantly, it gives pulse propagation speeds consistent with the experiment.

[1] P.Mantica et al.,Proc.19th Intern. Conf. on Fusion Energy, Lyon [IAEA,Vienna,2002] EX/P1-04.
[2] D. del-Castillo-Negrete, Phys. Plasmas 13, 082308 (2006).

GP8.00021 Numerical simulation of ETG fluid model in uniformly sheared $E \times B$ velocity , JUHYUNG KIM, Institute for Fusion Studies, University of Texas at Austin, GEORGE CHAGELISHVILI, Center for Plasma Astrophysics, Abastumani Astrophysical Observatory, Georgia, WENDELL HORTON, Institute for Fusion Studies, University of Texas at Austin — We construct an ETG fluid model (Horton et al. Nucl. Fusion 45, 2005) with uniformly sheared $E \times B$ velocity. The fluid model is implemented based on the pseudospectral method. The linear dynamics calculation is performed in the moving frame, where the periodicity is assumed in the Lagrangian coordinate, and the nonlinear term is implemented in the traditional Fourier transformation (Lithwick, arXiv:astro-ph/0702046, 2007). This method enables us to investigate the nonlinear dynamics in sheared flow at a typical growth rate $\gamma > \omega_E$, for which we observed long-lived vortex structures when no instability is included (Kim et al. Phys. Plasma 13, 2304, 2006). We will report the spectrum for the electrostatic potential and the temperature.

GP8.00022 Feedback of large-scale fluctuations on driving noise , CHANG-BAE KIM, Soongsil University — The so-called predator-prey model that describes the dynamics of large-scale fluctuations and short-scale turbulence is studied by substituting the turbulence with noise. It is known that large-scale fluctuations in the plasma driven by the parity-nonconserving (PNC) noise become unstable if the relative level of the PNC noise is over a threshold $\alpha_c = logR/R$, where R is the ratio of the largest to the smallest scales. The PNC noise may model such short-scale turbulence as the drift waves of short wave lengths. As a result, large-scale fluctuations emerge and grow in time. If this is an action of the turbulence on large scales, the reaction of the large-scale fluctuations on the turbulence is to lower the effective strength of the PNC noise below the threshold in order to make the plasma reach stationary state. This feedback is worked out by renormalizing the noise up to the lowest nontrivial order. It will be shown that the isotropic part of the noise is enhanced while the PNC piece being unchanged and that, as a result, the relative strength of the PNC to the isotropic noise is smaller than α_c.

GP8.00023 Ion-Acoustic Turbulence in ECCD-driven TCV plasmas , CHRISTIAN SCHLATTER, BASIL P. DUVAL, ALEXANDER N. KARPUSHOV, TIMOTHY P. GOODMAN, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas, Association Euratom-Confederation Suisse, CH-1015 Lausanne — Strong X2 electron-cyclotron current drive in the Tokamak à Configuration Variable (TCV) is typically accompanied by rapid (non-collisional) and strong bulk ion heating. Neutral Particle Analyzer (NPA) measurements of the ion properties transverse to the toroidal magnetic field indicate suprathermal ion populations comprising more than 20 % of the ions with temperatures up to several keV [1]. Whereas the RF power is deposited in the very plasma center, fast ions are found almost throughout the plasma column. Theoretical calculations of the EC driven current are combined with experimental estimations of the relativistic electron drift velocities using oblique ECE measurements in order to assess the conditions to trigger ion-acoustic turbulence, which is believed to be responsible for the ion heating [2]. An attempt of numerically modeling the experimentally observed level of turbulence saturation in the frame of quasi-linear theory will be presented.

References: [1] A. N. Karpushov et al., 33rd EPS Conference on Plasma Phys. Rome (2006); [2] Ch. Schlatter et al., dito.

GP8.00024 FACETS: Towards a flexible infrastructure for building coupled transport models[1] , ALEXANDER PLETZER, Tech-X, AMMAR HAKIM, MAHMOOD MIAH, SRINATH VADLAMANI, JOHAN CARLSSON, SCOTT KRUGER, JOHN R. CARY, ALEXEI PANKIN, Lehigh U. — The Framework Application for Core-Edge Transport Simulation (FACETS) is a project aimed at providing an infrastructure for building transport codes capable of exploiting massively parallel architectures. FACETS is driven by the requirement to simulate $>$ 100s long discharges in ITER, with time scales ranging from μs for plasma wall-interactions to 1s for the slow evolution equilibrium profiles. Critical to FACETS will be the capability to couple physics modules (transport models, neutral beam sources, equilibrium, ...) in flexible and efficient way. We report on the progress of building such an infrastructure. FACETS introduces the concept of components and updaters. Components hold data such as profiles while updaters act on these data, for example by time-advancing fields. As an example, we show how to create building block components and updaters for a core transport code, which uses an implicit algorithm based on the block hyper-secant method (BHS solver) to advance ion/electron densities and temperatures. Fluxes are computed by FMCFM's uniform interface to the GLF23/MMM95 reduced transport models.

[1]SciDAC DE-FG03-98ER54487.

GP8.00025 Transport in two-fluid MHD turbulence , ELLEN KUMAR, E. KIM, Univ. of Sheffield — We present a theory of transport of magnetic flux and momentum in two fluid 3D reduced magnetohydrodynamic (MHD) turbulence. By including the effects of shear flows and magnetic fields consistently, we show that kinetic Alfven waves can help weaken the quenching in turbulent transport of a strong magnetic field B_0 found in single fluid MHD turbulence, leading to turbulent diffusivity $\eta_T \propto (\eta/\Omega)^{1/3} B_0^{-2}$. Here, η and Ω are Ohmic diffusivity and shearing rate of the shear flow. Momentum transport is diffusive, with the value of eddy viscosity larger than that in single fluid MHD turbulence. The effects of drift waves are found to be weaker. Implications for the instability of shear flows are discussed.

GP8.00026 Turbulent resistivity in wavy 2D MHD turbulence[1] , SHANE KEATING, PATRICK DIAMOND, University of California, San Diego — The theory of 'wavy' MHD turbulence in 2D is presented. The goal is to explore the theory of quenching of turbulent resistivity in a regime for which the mean field theory can be rigorously constructed at large magnetic Reynolds number Rm. We extend the simple 2D problem to include body forces such as buoyancy or the Coriolis force, which convert large scale eddys into weakly interacting dispersive waves. The turbulence- driven spatial flux of magnetic potential is calculated to fourth order in wave slope. Remarkably, adding an additional restoring force to the already tightly constrained system of high Rm MHD turbulence in 2D can actually increase turbulent resistivity, by admitting a spatial flux of magnetic potential which is not quenched at large Rm, although it is restricted by the conditions of applicability of weak turbulence theory.

[1]Supported under US DoE grant DE-FG02-04ER54738.

GP8.00027 Numerical modeling of anisotropic 3D Drift-Alfven turbulence , J.C. PEREZ, STANISLAV BOLDYREV, University of Wisconsin-Madison — We present results from extensive numerical simulations of steady state Drift-Alfven turbulence in the presence of a strong guide field. We use a turbulence model based on equations originally derived by Hazeltine as an extension of the Reduced MHD model (RMHD). The model includes three dynamical fields, potential, magnetic flux, density and allows for the existence of a background density gradient that drives large scale electromagnetic drift-wave instabilities. Previous numerical simulations of this type of models have been mostly restricted to 2D or pseudo 2D simulations in the limit of vanishing $k_\parallel$, which restrict the turbulence cascade to the field-perpendicular plane. However, recent work in MHD turbulence have shown that the parallel dynamics can play a key role in anisotropic turbulent cascades. In this work we present fully 3D simulations of strong Drift-Alfven turbulence in a rectangular box that reflects the anisotropy of the turbulence imposed by the guide field. Simulations are benchmarked against state-of-the-art simulations of MHD turbulence at large scales and are used to investigate the energy spectrum as the turbulence reaches the ion sound radius, where the Shear Alfven makes the transition to a Kinetic Alfven wave.

GP8.00028 Numerical Simulations of Strong MHD Turbulence[1] , J. MASON, F. CATTANEO, University of Chicago, S. BOLDYREV, University of Wisconsin — Magnetohydrodynamic turbulence plays an important role in many astrophysical phenomena, including the solar wind, angular momentum transport in accretion disks and interstellar scintillation. Despite more than 40 years of investigations much within the subject remains controversial. Recently a new theory has been developed [1, 2]. It predicts a scale-dependent dynamic alignment between the velocity and magnetic fluctuations and leads to the field-perpendicular energy spectrum $E(k) \propto k^{-3/2}$. Here we discuss this new theory and present the results of a series of numerical tests. Quantities measured include the alignment angle, the spectrum and the third order structure functions for which the exact relations due to Politano & Pouquet [3] hold.

[1] Boldyrev, S. (2005) Astrophys. J. 626, L37.
[2] Boldyrev, S. (2006) Phys. Rev. Lett. 96, 115002.
[3] Politano, H. & Pouquet, A. (1998) Geophys. Res. Lett. 25, 273.

[1]This work is funded by the NSF sponsored Center for Magnetic Self-Organization.

GP8.00029 A laboratory study of a nonlinear interaction between co-propagating kinetic Alfven waves[1] , B.T. BRUGMAN, T.A. CARTER, D.W. AUERBACH, S.C. COWLEY, Dept. of Physics and Astronomy and CMPD, UCLA — A study of a beat-wave interaction between kinetic Alfvén waves has been performed in the Large Plasma Device (LAPD) at UCLA[2]. Two co-propagating waves are observed to beat together and drive a strong low-frequency mode which has a normalized amplitude comparable to or exceeding that of the two incident Alfvén waves ($\delta n/n > \delta B/B \sim 1\%$). This low-frequency mode then interacts with the incident Alfvén waves, leading to strong sideband generation. The phase velocity beat-driven mode is consistent with three-wave matching rules, but is not consistent with any linear wave. A nonlinear Braginskii fluid model of the interaction predicts that the beat-driven wave is a quasimode that is really an off-resonance Alfvén wave. The quasimode is driven by nonlinear cross-field convection which is effective due to the short perpendicular scale of the incident Alfvén waves ($k_\perp \gg k_\parallel$). The model predicts a sizable amplitude for the beat-driven response, consistent with experimental observations. Details of experimental observations and the nonlinear model will be presented.

[1]Supported by NSF grant no. PHY-0547572 and DOE cooperative agreement DE-FC02-04ER54785
[2]T.A. Carter, *et al.*, PRL 96, 155001 (2006)

GP8.00030 Heating and background plasma modification associated with large amplitude kinetic Alfvén wave launch in LAPD[1] , T.A. CARTER, D.W. AUERBACH, B.T. BRUGMAN, Dept. of Physics and Astronomy and CMPD, UCLA — Large amplitude kinetic Alfvén waves ($\delta B/B \sim 1\% > k_\parallel/k_\perp$) are generated in the Large Plasma Device (LAPD) at UCLA using loop antennas. Substantial electron heating is observed, localized to the wave current channels. The Poynting flux associated with the Alfvén waves is substantial and the observed heating may be at least in part due to collisional and Landau damping of these waves. However, heating by antenna near inductive electric fields may also be responsible for the observations. A discussion of both possibilities will be presented, including measurements of near fields of the antenna. The heating structures the background plasma and results in the excitation of drift-Alfvén waves. These drift waves then interact with the incident Alfvén wave, causing sideband generation which results in a nearly broadband state at high wave power. This process may represent an alternate mechanism by which unidirectional kinetic Alfvén waves can nonlinearly generate a turbulent spectrum. In addition to electron heating, evidence for background density modification and electron acceleration is observed and will be presented.

[1]Supported by NSF grant no. PHY-0547572 and DOE cooperative agreement DE-FC02-04ER54785.

GP8.00031 Studies of nonlinear interactions between counter-propagating Alfvén waves in the LAPD[1] , D.W. AUERBACH, UCLA, J.C. PEREZ, UW-Madison, T.A. CARTER, UCLA, S. BOLDYREV, UW-Madison — From a weak turbulence point of view, nonlinear interactions between shear Alfvén waves are fundamental to the energy cascade in low-frequency magnetic turbulence. We report here on an experimental study of counter-propagating Alfvén wave interactions in the Large Plasma Device (LAPD) at UCLA. Colliding, orthogonally polarized kinetic Alfvén waves are generated by two antennae, separated by 5m along the guide magnetic field. Magnetic field and langmuir probes record plasma behavior between the antennae. When each antenna is operated separately, linearly polarized Alfvén waves propagate in opposite directions along the guide field. When two antennae simultaneously excite counter propagating waves, we observe multiple side bands in the frequency domain, whose amplitude scales quadratically with wave amplitude. In the spatial domain we observe non-linear superposition in the 2D structure of the waves and spectral broadening in the perpendicular wave-number spectrum. This indicates the presence of nonlinear interaction of the counter propagating Alfvén waves, and opens the possiblity to investigate Alfvénic plasma turbulence in controlled and reproducible laboratory experiments.

[1]Support From NSF PHY-0547572 and DOE DE-FC02-04ER54785.

GP8.00032 Effect of ion composition on magnetosonic waves

, MIEKO TOIDA, Nagoya University, HIROYUKI HIGASHINO, YUKIHARU OHSAWA — The propagation of the two kinds of fast magnetosonic waves, i.e., low- and high-frequency modes, in a two-ion-species plasma is studied theoretically and numerically. It is analytically found that the KdV equation for the low-frequency mode is valid for amplitudes $\varepsilon < 2\Delta_\omega$, where $\Delta_\omega = (\omega_{+0} - \omega_{-\mathrm{r}})/\omega_{+0}$ with ω_{+0} the cutoff frequency of the high-frequency mode and $\omega_{-\mathrm{r}}$ the resonance frequency of the low-frequency mode; Δ_ω is given as a function of the density ratio and cyclotron frequency ratio of two ion species. It is then suggested that nonlinear coupling between the two modes can occur if $\varepsilon > 2\Delta_\omega$. With electromagnetic particle simulations, the evolution of the low- and high-frequency-mode pulses is investigated for various density and cyclotron frequency ratios and is compared with theoretical predictions. In particular, it is shown that high-frequency-mode pulses are generated from a long-wavelength low-frequency-mode pulse if its amplitude ε exceeds $2\Delta_\omega$.

GP8.00033 A non-linear 4-wave resonant model for non-perturbative fast ion interactions with Alfvénic modes in burning plasmas

, FULVIO ZONCA, Associazione EURATOM-ENEA sulla Fusione, LIU CHEN, Department of Physics and Astronomy, University of California, Irvine — We adopt the 4-wave modulation interaction model, introduced by Chen et al [1] for analyzing modulational instabilities of the radial envelope of Ion Temperature Gradient driven modes in toroidal geometry, extending it to the modulations on the fast particle distribution function due to nonlinear Alfvénic mode dynamics, as proposed in Ref. [2]. In the case where the wave-particle interactions are non-perturbative and strongly influence the mode evolution, as in the case of Energetic Particle Modes (EPM) [3], radial distortions (redistributions) of the fast ion source dominate the mode nonlinear dynamics. In this work, we show that the resonant particle motion is secular with a time-scale inversely proportional to the mode amplitude [4] and that the time evolution of the EPM radial envelope can be cast into the form of a nonlinear Schrödinger equation a la Ginzburg-Landau [5].

[1] L. Chen et al, Phys. Plasmas **7** 3129 (2000)
[2] F. Zonca et al, Theory of Fusion Plasmas (Bologna: SIF) 17 (2000)
[3] L. Chen, Phys. Plasmas **1**, 1519 (1994).
[4] F. Zonca et al, Nucl. Fusion **45** 477 (2005)
[5] F. Zonca et al, Plasma Phys. Contr. Fusion **48** B15 (2006)

GP8.00034 Positive and negative effective mass of relativistic particles in oscillatory and static fields[1]

, I.Y. DODIN, N.J. FISCH, Princeton University — A relativistic particle oscillating in high-frequency and/or static fields can be treated as a quasiparticle with an effective mass m_{eff}, which depends on the local parameters of the fields. Both ponderomotive and $\mu\nabla B$ forces, as well as magnetic drifts, are derived from $m_{\mathrm{eff}} = m_{\mathrm{eff}}(\mathbf{r}, \dot{\mathbf{r}})$, $\mathbf{r}$ being the coordinate of the oscillation center. The effective mass is not necessarily positive; thus, if a (weak) external force is applied, acceleration in the direction opposite to this force is possible. As an example, adiabatic average dynamics with $m_{\mathrm{eff}} > 0$ and $m_{\mathrm{eff}} < 0$ is demonstrated for a wave-driven particle in a dc magnetic field. Different energy states are realized in this case, yielding up to three branches of m_{eff} for a given magnetic moment and parallel velocity.

[1]The work is supported by DOE Contract No. DE-FG02-05ER54838 and by the NNSA under the SSAA Program through DOE Research Grant No. DE-FG52-04NA00139.

GP8.00035 A water bag theory of autoresonant BGK modes[1]

, PAVEL KHAIN, LAZAR FRIEDLAND, Hebrew University of Jerusalem — The adiabatic water bag theory describing formation and passage through phase-space of driven, continuously phase-locked (autoresonant) coherent structures in plasmas [L. Friedland et al., Phys. Rev. Lett. **96**, 225001 (2006)] and of the associated BGK modes is developed. The phase-locking is achieved by using a chirped frequency ponderomotive drive, passing through kinetic Cherenkov-type resonances. The theory uses the adiabatic invariants (conserved actions of limiting trajectories) in the problem and, for a flat-top initial distribution of the electrons, reduces the calculation of the self-field of the driven BGK mode to solution of a few algebraic equations. The adiabatic multi-water bag extension of the theory for applications to autoresonant BGK structures with more general initial distributions is suggested. The results of the theories are in a very good agreement with numerical simulations.

[1]Supported by the Israel Science Foundation, Grant No. 294/05.

GP8.00036 Nonlinear Wave and Soliton Excitations in Coasting Charged Particle Beams Using a Kinetic g-Factor Model[1]

, RONALD DAVIDSON, EDWARD STARTSEV, HONG QIN, PPPL — Making use of a one-dimensional kinetic model based on the Vlasov-Maxwell equations, this paper describes nonlinear wave and soliton excitations in coasting charged particle beams. The kinetic description is based on the recently-developed g-factor model [1] that incorporates self-consistently the effects of transverse density profile shape at moderate beam intensities. The nonlinear evolution of wave and soliton excitations is examined [2] for disturbances both moving faster and moving slower than the sound speed, incorporating the important effects of wave dispersion. Analytical solutions are obtained for nonlinear traveling wave pulses, and the results of nonlinear perturabtive particle-in-cell simulations are presented that describe the stability properties and long-time evolution.

(1) R. C. Davidson and E. A. Startsev, Phys. Rev. ST Accel. Beams 7, 024401 (2004).
(2) R. C. Davidson, E. A. Startsev and H. Qin, Proceedings of the 2007 Particle Accelerator Conference, in press (2007)

[1]Research supported by the U. S. Department of Energy

GP8.00037 KEEN Waves, Conformal Invariance and Connections to 2D Euler Turbulence Theory[1]

, BEDROS AFEYAN, MATHIEU CHARBONNEAU-LEFORT, Polymath Research Inc. — KEEN Waves are a manifestation of nonstationary, self-organized, nonlinear, kinetic states shown to be prevalent in coherently driven plasmas [1]. We will examine statistical mechanical and conformal invariance in critical phenomena based arguments that try to explain the existence and salient features of such states as well as indicating mechanisms by which turbulence and disorder are beaten in order to generate them. The connection with 2D Euler turbulence [2], multifractal characterizations of critical phase transitions and Schramm-Loewner evolutions will be given.

[1] B. Afeyan, et al., Kinetic Electrostatic Electron Nonlinear (KEEN) Waves and their interactions driven by the ponderomotive force of crossing laser beams, Proc. IFSA, (Inertial Fusion Sciences and Applications 2003, Monterey, CA), B. Hammel, D. Meyerhofer, J. Meyer-ter-Vehn and H. Azechi, editors, 213, American Nuclear Society, 2004.
[2] Bernard, et al., Nature Phys. 2, 124 (2006) and references therein.

[1]Work supported by a DOE NNSA SSAA Grant.

GP8.00038 Destruction of transport barriers in a nontwist map model of a reversed magnetic shear tokamak with an ergodic magnetic limiter

, ALEXANDER WURM, Dept. of Physical and Biological Sciences, Western New England College — Recently, the magnetic field line structure of reversed magnetic shear tokamaks has been modeled by an area preserving nontwist map that includes non-integrable perturbations describing ergodic magnetic limiters.[1] An expansion around the equilibrium shearless curve (corresponding to the main transport barrier in the model) showed that the map is locally equivalent to the standard nontwist map with an additional perturbation due to the limiter.[2] I report results of the investigation into the effect of the perturbation on the resilience of the shearless curve.

[1] K. Ullmann and I.L. Caldas, Chaos, Solitons and Fractals, **11**, 2129 (2000).
[2] J.S.E. Portela, I.L. Caldas, R.L. Viana, and P.J. Morrison, to appear in J. Bifur. Chaos (2007).

GP8.00039 FAST IGNITION AND LASER-PLASMA INTERACTIONS —

GP8.00040 Hydrodynamic assembly for Fast Ignition[1]

, MAX TABAK, DANIEL CLARK, RICHARD TOWN, STEPHEN HATCHETT, Lawrence Livermore National Laboratory — We present directly and indirectly driven implosion designs for Fast Ignition. Directly driven designs using various laser illumination wavelengths are described. We compare these designs with simple hydrodynamic efficiency models. Capsules illuminated with less than 1 MJ of light with perfect zooming at low intensity and low contrast ratio in power can assemble 4 mg of fuel to column density in excess of 3 g/cm^2. We contrast these designs with more optimized designs that lead to Guderley-style self similar implosions. Indirectly driven capsules absorbing 75 kJ of xrays can assemble 0.7 mg to column density 2.7 g/cm^2 in 1D simulations. We describe 2-D simulations including both capsules and attached cones driven by radiation. We describe issues in assembling fuel near the cone tip and cone disruption.

[1]Work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

GP8.00041 Fast Ignition with Ultra-High Intensity Lasers

, JOHN TONGE, M. TZOUFRAS, F.S. TSUNG, W.B. MORI, UCLA, C. REN, University of Rochester, M. MARTI, L. SILVA, Instituto Superior Tecnico — Energy transport within overdense plasma with a fast ignition target is explored by examining the interaction of different intensity ignition lasers with a 50 μ radius target using two-dimensional Particle-In-Cell simulation. In fast ignition schemes the ignition energy must be delivered to a small region ($\sim$ 20 μ in radius) of dense plasma within the target in order to create a localized region where fusion occurs. The electron stopping length in the core and the energy spectrum of the ignition electrons determines the depth of this region. This depth is sensitive to the spectrum of the energy flux of fast electrons generated as a function of laser intensity at the critical surface. Coupled with current assumptions of the spectrum of electrons generated by high intensity lasers this limits ignition laser intensity to 5x10^{19} W/cm^2. Our simulations show that the peak energy flux of the ignition electrons is significantly lowered as the electrons traverse the collisionless plasma from the critical density surface of the plasma to the high density target core where ignition occurs. This allows higher intensity lasers to be used thus delivering power to a narrower region. In addition we find that a higher percentage of the ignition lasers energy is delivered to the core with the higher intensity laser.

GP8.00042 Observations of the Effect of Er-Hydride Targets on the Conversion Efficiency to Laser Accelerated Protons[1]

, D.T. OFFERMANN, L.D. VAN WOERKOM, The Ohio State University, Columbus, OH, A.J. MACKINNON, Y. PING, A.G. MACPHEE, N. SHEN, M.E. FOORD, J.J. SANCHEZ, Lawrence Livermore National Laboratory, Livermore, CA, C.D. CHEN, Massachusetts Institute of Technology, Cambridge, MA — For Fast Ignition Inertial Confinement Fusion using proton beams, methods must be developed to improve the efficiency in converting laser energy incident on thin foils to the accelerated proton beam from the foil's rear surface. Simulations suggest that targets with a heavy element hydride, such as ErH_3, on the rear surface will increase the conversion efficiency by a factor of two relative to proton signals originating from hydrocarbon contaminants. Using the Callisto Laser, at LLNL ((8J, 5$\times$10^{19} W/cm^2)) we have compared proton beams originating from contaminant layers on Gold foil targets with beams from Gold targets coated with ErH_3. Contaminants were removed using an Ar-Ion etching beam. Data was collected using radiochromic film and an ion spectrometer.

[1]Work was performed under the auspices of the U.S. Dept of Energy by University of CA, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

GP8.00043 Proton Focusing in a FI Target Compatible Configuration[1]

, R.B. STEPHENS, GA, A.J. MACKINNON, S.P. HATCHETT, M.H. KEY, B.F. LASINSKI, B. LANGDON, P.K. PATEL, M. FOORD, M. TABAK, R.P.J. TOWN, S.C. WILKS, LLNL, M.S. WEI, F. BEG, S. CHEN, R.R. FREEMAN, J.A. KING, J. PASLEY, UCSD, K.U. AKLI, D. CLARK, L. VAN WOERKOM, Ohio State U., D. HEY, UC-Davis — FI targets that use laser-generated proton beams for ignition must protect the proton-generating surface from the imploding shell. The protective case surrounding the surface has the potential to change the ion production efficiency and its focus. We have explored these effects in recent experiments on the Titan laser with a focusing surface embedded in a washer. The proton beam was recorded with a radiochromic film stack. The shadow of a 1000 lpi SEM grid mounted beyond the nominal focus of the proton surface ($\sim$1.8x radius of curvature) allowed the calculation of focal point position and size as a function of proton energy. Simultaneous XUV measurements of the heated grid give total proton energy deposited in the grid. Experimental results will be compared to simulations.

[1]Supported by the US DOE under DE-FG02-05ER54834 and W-7405-ENG-48, and support of the Ohio State University and the Herz Foundation.

GP8.00044 Capsule Design Studies for Mid-Z Ion-Driven Fast Ignition[1]

, B.J. ALBRIGHT, M.J. SCHMITT, G.E. CRAGG, J.C. FERNÁNDEZ, I.L. TREGILLIS, N.M. HOFFMAN, G.R. MAGELSSEN, B.M. HEGELICH, K.A. FLIPPO, Los Alamos National Laboratory — Ion fast ignition (IFI) is an approach to fast ignition inertial confinement fusion where an energetic ion beam is used to ignite a hot spot. Recent work at LANL and elsewhere has shown that energetic mid-Z ion beams can be made when one directs a high- intensity short-pulse laser onto a target foil cleaned to remove impurities. Use of such mid-Z ion beams in IFI may have advantages over other approaches to fast ignition. In this presentation, preliminary capsule designs for mid-Z IFI are assessed. These designs comprise a DT gas pocket, a DT ice fuel layer, and a low-Z ablator. Dependence of gain with beam parameters will be shown and the viability of this approach to fast ignition will be discussed.

[1]Work performed under the auspices of the U.S. Dept. of Energy by the Los Alamos National Security LLC Los Alamos National Laboratory under contract No. DE-AC52-06NA25396 and supported by the LANL LDRD program.

GP8.00045 Liquid Cryogenic Target Development for Fast Ignition* , D.L. HANSON, C. RUSSELL, R.A. VESEY, Sandia National Laboratories, D.G. SCHROEN, J.L. TAYLOR, C.A. BACK, D. STEINMAN, A. NIKROO, J.L. KAAE, E. GIRALDEZ, General Atomics, R.R. JOHNSTON, K. YOUNGMAN, Ktech Corp. — As an alternative to foam-stabilized cryogenic solid D-T fuel layers for indirect-drive fast ignitor targets, which will tend to β-layer to a nonuniform distribution in a reentrant cone geometry [1], we are investigating hemispherical cryogenic fast ignition capsules with a liquid fuel layer confined between a thick outer ablator shell and a thin inner shell [2]. The shape and surface quality of the fuel layer is determined entirely by the characteristics of the bounding shells. In the present design, structural support for the thin (4.5 um) hemispherical GDP inner shell is provided by a mounting ring. Fabrication of stronger thin Be hemi-shells is also being investigated. Technology issues for liquid cryogenic fuel capsule development and progress toward demonstration of a working target will be presented.
[1] J.K. Hoffer *et al.*, Fusion Sci. Technol. **50**, 15 (2006).
[2] D.L. Hanson *et al.*, Fusion Sci. Technol. **49**, 500 (2006).
*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

GP8.00046 PIC simulations of energetic electron transport in fast ignition[1] , XIANGLONG KONG, RUI YAN, CHUANG REN, University of Rochester — Transport of an energetic electron beam in a plasma is studied via PIC simulations with beam-plasma parameters and boundary conditions relevant to fast ignition. This system is subject to current-filamentation and two-stream instabilities [Tonge, PhD thesis (2002), Bret, Firpo, and Deutsch, PRE, 70:046401 (2004)]. The simulations show that the current filaments resulting from the instabilities do not merge into a single filament as in the previous 2D simulations excluding the two-stream instability [Lee and Lampe, PRL, 31:1390 (1971)]. The effects of ions and boundary conditions on the current filamenting and merging will also be presented.

[1]This work was supported by the U.S. Department of Energy under Grant Nos. DE-FC02-04ER54789 and DE-FG02-06ER54879

GP8.00047 PIC simulations of energetic electron generation from laser-plasma interactions[1] , RUI YAN, GANG LI, CHUANG REN, University of Rochester — Energetic electron generation from laser-plasma interactions is important to inertial confinement fusion in many ways. Using particle-in-cell (PIC) simulations we study the energetic electrons generation from Raman/two-plasmon-decay instabilities near the 1/4-critical surface. The possibility of target preheating from these electrons will be examined for the Omega laser parameters. We also study the energetic electron generation in the parameter regime relevant to fast ignition. Both 2D and 3D simulations are carried out to study different electron acceleration mechanisms near the laser-plasma interface between linearly-polarized and circularly-polarized lasers. Energetic electron conversion efficiency and angular spread will be compared for the two polarizations.

[1]Supported by the U.S. Department of Energy under Grant Nos. DE-FC02-04ER54789 and DE-FG02-06ER54879.

GP8.00048 Laser channeling in mm-scale underdense plasmas of fast ignition[1] , C. REN, G. LI, R. YAN, University of Rochester, T.L. WANG, J. TONGE, W.B. MORI, UCLA — Two dimensional particle-in-cell simulations show that laser channeling in mm-scale underdense plasmas is a highly nonlinear and dynamic process involving laser self-focusing and filamentation, channel expansion through ponderomotive blowout and high mach number shock waves, plasma density snowplowing, laser hosing, and channel bifurcation and merging. The channeling speed is much less than the laser linear group velocity. The simulations find that the channeling time T_c and the total required energy E_c to reach the critical surface scale with the laser intensity I as $T_c \sim I^{-0.64}$ and $E_c \sim I^{0.36}$. The scaling shows that low-intensity channeling pulses are preferred to minimize the required pulse energy but with an estimated lower bound on the intensity of $I \approx 4\times 10^{18}$W/cm^2 if the channel is to be established within 100ps. These results will also be compared with those from smaller scale 3D simulations.

[1]Work supported by the U.S. Department of Energy under Cooperative Agreement and Grant Nos. DE-FC52-92SF19460, DE-FC02-04ER54789, and DE-FG02-06ER54879.

GP8.00049 Hot electron energy coupling in cone-guiding fast ignition , BRIAN CHRISMAN, YASUHIKO SENTOKU, University of Nevada, Reno, ANDREAS KEMP, LLNL, THOMAS COWAN, University of Nevada, Reno — The Fast Ignition experiment relies on core ion heating due to laser-plasma interactions. Potential underlying mechanisms for core ion heating include field instabilities, coronal ion wave incidence, and collisional coupling of energetic electrons accelerated from the coronal plasma.Previously demonstrated results show that after preplasma has been swept away, the ultra-intense laser interacts with a steep density gradient, producing low energy hot electrons which are capable of penetrating and interacting with the high density core through collisional processes.Resolving known relevant physics in integrated 2D PIC simulations of a representative Fast Ignition experiment, simulation results are provided detailing the dependence of comprehensive core heating upon laser intensity.

GP8.00050 Saturation and Long-Time Behavior of Weibel Instability and Electron Beam Transport in Dense Plasmas[1] , OLEG POLOMAROV, GE WANGE, GENNADY SHVETS, IFS, University of Texas at Austin, ADAM SEFKOW, IGOR KAGANOVICH, PPPL, Princeton University — The propagation of electron beams in ambient plasma is considered analytically and numerically. For analytical treatment the two-fluid hydrodynamics for beam and plasma electrons is used. Two numerical approaches are used: the reduced description [PoP, 14, 043103 (2007)] (in which the beam is modeled by particles and the plasma is an electron fluid) and the LSP PIC simulations. The detailed analysis of linear/non-linear stages and the saturation of the Weibel filamentation instability is presented and the instability long-term non-linear behavior is emphasized. For example, it is discovered that the filament formation and merger can lead to the growth as well as the decrease of the magnetic energy for sub/super-alfvenik filaments. The plausible final state to which the Weibel instability evolves for large times is presented. Also, the peculiarities of 1D, 2D and 3D spatial behavior of the Weibel and electrostatic two-stream instabilities of the relativistic electron beam propagating in constant density as well as in the steep gradient background plasmas (the Fast Ignition case) are considered.

[1]Supported by DOE through grant DE-FG02-05ER54840 and DE-FG02-04ER54763.

GP8.00051 The effect of laser intensity on fast electron beam divergence in solid density plasmas , V.M. OVCHINNIKOV, L. VAN WOERKOM, R.R. FREEMAN, The Ohio State University, J.S. GREEN, R.G. EVANS, R. HEATHCOTE, K.L. LANCASTER, P.A. NORREYS, RAL, UK, K.U. AKLI, M.H. KEY, A.J. MACKINNON, A.G. MACPHEE, LLNL, F.N. BEG, J.A. KING, T. MA, UCSD, R. STEPHENS, GA, C. BELLEI, Z. NAJMUDIN, Imperial College, UK, J. WAUGH, University of York, UK, H. AZECHI, Osaka University, Japan, P. NILSON, W. THEOBALD, LLE, Rochester, N.C. LOPES, R. ONOFREI, J.R. DAVIES, Instituto Superior Tecnico, Lisbon — Metal foil targets were irradiated with 1 μm wavelength (λ) laser pulses of 5 ps duration and focused intensities up to $4 \times 10^{19} W cm^{-2}$, giving values of both $I\lambda^2$ and pulse duration comparable to those required for fast ignition inertial fusion. The divergence of the electrons accelerated into the target was measured using spatially resolved X-ray $K_\alpha$emission and from transverse probing of the plasma formed on the back of the foils. Comparison of the divergence with other published data will be presented along with 2D PIC simulations. Supported by DOE grants DE-FG02-05ER54834, DE-FG02-00ER54606, and W-7405-Eng-48 and STFC (UK).

GP8.00052 Measurement of Hot Electron Spatial Distribution Under the Presence of Laser Light Self-focusing in Over-dense Plasmas , TSUYOSHI TANIMOTO, KAZUO A. TANAKA, ANLE LEI, TOSHINORI YABUUCHI, HIDEAKI HABARA, KIMINORI KONDO, RYOUSUKE KODAMA, Graduate School of Engineering, Osaka Univ., KUNIOKI MIMA, ILE, Osaka Univ. — In fast ignition (FI) scheme, ultra intense laser (UIL) pulse irradiates an imploded plasma core in order for fast heating via hot electrons generated in laser-plasma interactions. Two important issues are the propagation of forward directed hot electron in the plasma and the spatial divergence of hot electrons. We measured the spatial distribution of hot electrons with different plasma density profiles when UIL pulse creates laser self-focused plasma channel in pre-formed plasma. When the self-focusing occurred, the hot electron number increased and the spatial distribution of hot electrons appeared more collimated . These hot electron distributions may be preferred for a high efficiency core heating in FI scheme.

GP8.00053 Simulation Studies on Fast Heating for FIREX-I project , TOMOYUKI JOHZAKI, HIDEO NAGATOMO, ILE, Osaka University, HITOSHI SAKAGAMI, NIFS, TATSUFUMI NAKAMURA, ATSUSHI SUNAHARA, ILE, Osaka University, YASUYUKI NAKAO, Kyushu University, KUNIOKI MIMA, ILE, Osaka University — At the fast ignition integrated experiments for cone-guided CD targets with GekkoXII+PW laser systems [1], the efficient heating of imploded cores (~800eV) was demonstrated. As the next step, FIREX (Fast Ignition Realization EXperiment) project [2] has been started. In the phase I (FIREX-I), a foam-cryogenic DT target is imploded by the GekkoXII laser operated with higher energy mode and the imploded core is heated by the 10kJ LFEX laser. The goal of FIREX-I is the core heating up to ion temperature of ~5keV. From the previous experiments, the heating laser energy and the fuel material are different in FIREX-I. In the present study, on the basis of core heating simulations for imploded core plasmas, where the core heating is treated with a simple heating model and the Fokker-Planck transport model, we evaluate those effects and show the requirement for achieving 5keV heating.
[1] R. Kodama, et al., Nature 418, 933 (2002).
[2] K. Mima, Annual Progress Rep. 2001 (Institute of Laser Engineering, Osaka University, 2001) p.1.

GP8.00054 Optimization of Non-spherical Implosion for Fast Ignition[1] , HIDEO NAGATOMO, TOMOYUKI JOHZAKI, TATSUFUMI NAKAMURA, ILE, Osaka University, ATSUSHI SUNAHARA, ILT, HITOSHI SAKAGAMI, National Institute for Fusion Science, KUNIOKI MIMA, ILE, Osaka University — We have been studied the formation of high-density and high-areal-density core plasma in cone-guided non-spherical implosion for Fast Ignition. Sophisticated target designs are required, in which not only the target structure and laser pulse shape but also the detail specifications of the high density fuel core plasma for the high heating efficiency. Recently, we started the target design for the high-density better configuration of core plasma for heating in realistic conditions using 2-D radiation hydrodynamic code. Some sophisticated ideas, such as, a slow implosion for high density, high areal density concept [1] are taken account into. This concept is based on the 1-D implosion and 2-D effect caused by the guiding cone can not be ignored. Therefore, we have investigated the effect numerically. Also, the robustness over the hydrodynamic instabilities is studied. In this paper, these results are introduced and the best target design concept will be proposed, especially for FIREX-I experiment.
[1] R. Betti et al., PoP (2005).

[1]This work is supported by MEXT, Grant-in Aid for Creative Scientific Research (15GS0214)

GP8.00055 Partial degeneracy effects in the stopping of relativistic electrons in supercompressed DT fuels , KONSTANTIN STARIKOV, KazNu Almaty, CLAUDE DEUTSCH, LPGP UParis XI, STARIKOV COLLABORATION — The effects of supercompressed and partially degenerate electron fluid on projectile energy loss of femtolaser Produced relativistic electrons (REB) in the MeV energy range are investigated.Partial degeneracy is shown to effect Significantly the REB stopping power for 0.2 < Theta=T/Tf < 1 while its variations with beam energy appear much less Theta-dependent.The latter exhibit a characteristic V-like shape at any target electron density and Theta value.

GP8.00056 Measurements of Bremsstrahlung and K-shell Emission to Determine the Hot Electron Temperature and Conversion Efficiency in Short-pulse Laser Experiments[1] , C.D. CHEN, Plasma Science Fusion Center, Massachusetts Institute of Technology, J.A. KING, F.N. BEG, Department of Mechanical and Aerospace Engineering, University of California-San Diego, A.G. MACPHEE, M.H. KEY, A.J. MACKINNON, Lawrence Livermore National Laboratory, L. VAN WOERKOM, College of Mathematical and Physical Sciences, Ohio State University — Understanding the conversion efficiency and temperature spectrum of relativistic electrons produced via laser-plasma interactions is an essential first step for determining the coupling of laser energy to the compressed core of a fast ignition target. Measurements of the Bremsstrahlung spectrum and k-shell yield were made using a differentially filtered imaging plate spectrometer and a single-hit CCD spectrometer on various foil and cone targets irradiated with the TITAN laser (1054 nm, 150 J, 10^{20} W/cm^2) at Lawrence Livermore National Laboratory. The temperature and absolute number of relativistic electrons have been inferred from these x-ray measurements using the Monte Carlo code Integrated Tiger Series (ITS) 3.0.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

GP8.00057 Enhanced harmonic generation by relativistic laser interaction with a nanostructured target , XAVIER LAVOCAT-DUBUIS, JEAN-PIERRE MATTE, INRS-EMT, Un. du Quebec — The interaction of an ultra short (10 fs FWHM), ultra high intensity ($I\lambda^2 > 10^{10}$W) with a solid density target with a surface grating was simulated with the 2D relativistic PIC code XOOPIC [1], and compared to simulations with a smooth target surface. Very strongly enhanced emission at the wavelength of the grating period and its harmonics was obtained, nearly parallel to the target surface. The laser intensity required to obtain efficient harmonic emission was found to scale approximately with the square of the target density.
[1] J. Verboncoeur, A. Langdon, and N. Gladd, Comput. Phys. Commun. **87**, 199 (1995).

GP8.00058 Modeling High-Energy Backlighters Produced by Intense Laser-Matter Interaction[1] , GREGORY POLLAK, Los Alamos National Laboratory — The utility of reasonably monoenergetic, high frequency backlighters for radiographic use in high energy density physics experiments has been understood for a long time. A reasonable approach to generating these xrays is to use a high-intensity laser incident on suitable (typically mid-z) elements The deposition produces hot (non-thermal) electrons and ions, which ionize and excite inner shell electrons in a highly non-LTE environment Resulting xray generation often occurs in only a few bound-bound transitions. Because the hot electrons have substantial range, the lines can be optically thick. In this presentation, I use the radhydro code Lasnex to deposit both a prepulse and a main pulse of order 10^{18} to 10^{19} watts/cm^2 onto Ag and Sn substrates. The physical situation is then postprocessed using Plaspp, with an embedded DCA package to produce spectra. A unique feature of these simulations are the multiphoton inverse-bremstrallung and photoionization physics for deposition near the critical surface, as well as non-thermal collisional physics for the non-LTE spectra.

[1]Work supported by USDOE, performed at LANL, under contract DE-AC52-06NA25396

GP8.00059 Development of a collisional PIC code for an analysis of cluster plasmas, TOSHIHIRO TAGUCHI, Setsunan University, THOMAS ANTONSEN, HOWARD MILCHBERG, University of Maryland — We have developed a new particle-in-cell (PIC) code with ionization and collisional processes to analyze an interaction between a strong laser field and cluster plasmas. The code includes field and collisional ionization processes, electron-electron collisions by means of a Langevin type stochastic acceleration and electron-ion scattering. Using our new code, we analyzed the dynamics of a single cluster under a strong alternating electric field, which simulates a strong laser field in a range of 10^{14}–10^{17}W/cm^2. The results show that the code has a capability to simulate a dynamical behavior of an Argon cluster from the aggregation of neutral atoms to a rapidly expanding plasma heated by a strong laser field. The results also show that a resonant heating at a specific laser intensity whose value depends on a size of the cluster, as we reported in the references.

[1] T. Taguchi, et al., Phys. Rev. Lett., 92, 20, 2004, 205003.
[2] T. M. Antonsen, Jr., et al., Phys. Plasmas 12, 5, (2005), 056703.

GP8.00060 PIC Simulations of Short-Pulse, High-Intensity Light Interacting with Cone Targets[1], BARBARA F. LASINSKI, A. BRUCE LANGDON, C.H. STILL, MAX TABAK, RICHARD P.J. TOWN, Lawrence Livermore National Laboratory — In present day scenarios of fast ignition, a short-pulse high intensity laser propagates down a cone to produce hot electrons near the compressed core. Here we report on our continuing study of these cone irradiations in PIC simulations with our code, Z3. Previously we have shown[2] that in these PIC simulations, cones lead to increased absorption and higher laser intensities as compared to slab irradiations. Here, we report on the detailed spectra of the generated energetic electrons and in particular the increased hot electron temperature with cone irradiations. We look at the origin of these energetic electrons and their wide angular distribution. We vary the cone shape in both angle and the narrow end. And finally we consider the effect of underdense plasma created by a laser prepulse on these results.

[1]This work was performed under the auspices of the U. S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

[2]B. F. Lasinski, *et al*, 9^{th} International Fast Ignitor Workshop, Cambridge, Mass. (2006) and B. A. P. S. **51**, 294(2006).

GP8.00061 Quasi-monoenergetic ions from laser-triggered multi-stage particle acceleration[1], V. YU. BYCHENKOV, P.N. Lebedev Physics Institute, RAS, Moscow, Russia, G. I. DUDNIKOVA, Inst. of Computational Technologies, RAS, Novosibirsk, Russia, W. ROZMUS, R. FEDOSEJEVS, University of Alberta, Edmonton, Alberta, Canada, A. MAKSIMCHUK, FOCUS Center, University of Michigan, Ann Arbor, Michigan, USA — A production of high quality beams of ions has received considerable attention throughout the last few years because of their potential for applications in science, technology, and medicine. In this paper we present two schemes for laser generation of quasi-monoenergetic ion bunches based on 2D PIC simulations. In the first method quasi-monoenergetic ion bunch is generated by twin laser pulse involving a pre-pulse and subsiquent main pulse both of the ultra-short duration. The space-time parameters and energy spectrum are obtained. The second scheme exploits the effect of light ion acceleration at the heavy ion front. We found this effect to be well pronounced for moderate laser intensity ($\sim 10^{18}$ W/cm^2) and pulse duration ($\sim$1 ps) by using 2D PIC simulation of laser interaction with thin CD_2 foils. Quasi-monoenergetic deuterons form a jet from the rear side of the foil with the energy $\sim$1 MeV. The conversion efficiency to these quasi-monoenergetic ions is 10^{-3}.

[1]This work was partially supported by Russian Foundation for Basic Research (Grant No. 06-02-16103) the International Science and Technology Center (project No. 2289) and the Natural Sciences and Engineering Research Council of Canada.

GP8.00062 Energetic proton acceleration in ultra-intense laser interaction with super-low density targets, M. TAMPO, Institute of Laser Engineering Osaka Univ, R. KODAMA, K. HIGASHI, K. ENDO, K.A. TANAKA, Faculty of Engineering Osaka Univ, T. MATSUOKA, V. YANOVSKY, M. MAKSIMCHUK, G. KALINTCHENKO, K. KRUSHELNICK, Center for Ultrafast Optical Science University of Michigan, R. TEZUKA, H. YOKOGAWA, Matsushita Electric Works, Ltd., R. STEPHENS, General Atomics, T. NAKAMURA, K. MIMA, Institute of Laser Engineering Osaka Univ. — Aiming to increase the maximum energy of laser-accelerated proton beams, we have studied the relation between maximum proton energies and electron distribution functions, which determine electro-static sheath field to accelerate protons. We have proposed to increase the maximum proton energy using a distribution function of hot electrons produced by an interaction between ultra-short pulse laser ($<$ 100 f sec) and low density plasma ($< 10^{20}$ cm^{-3}). We have carried out the experiment using a silica foam (aerogel) with a density of 3mg /cc as a solid target and 30 f-sec short pulse laser light at the laser intensity of 10^{20} W/cm^2. We will report the result of the experiments and simulations.

GP8.00063 Preliminary high-energy x-ray measurements performed on the TRIDENT 250-TW laser[1], JONATHAN WORKMAN, J. COBBLE, K. FLIPPO, D.C. GAUTIER, S. LETZRING, M. SHERRILL, E.S. DODD, Los Alamos National Laboratory — We present preliminary measurements of K-alpha x-ray emission from foil and wire targets using copper, molybdenum and silver. Experiments are performed on the recently enhanced TRIDENT laser using 1-ps pulses at energies up to 100-J during this commissioning phase. 2-D images from static grids will be presented along with pinhole measurements of emission and single photon measurements from CCD cameras. Copper emission will be recorded on time-integrated crystal spectrometers. We will also present the design for a transmission crystal based high-energy spectrometer.

[1]Work performed under the auspices of the Dept. of Energy under contract # DE-AC52-06NA25396

GP8.00064 Specular Reflection of Intense Laser Light Interacting with Solid Targets[1], A. LINK, K. AKLI, D. OFFERMANN, V. OVCHINNIKOV, L. VAN WOERKOM, R.R. FREEMAN, The Ohio State University, Columbus, OH, H. CHEN, I. JOVANOVIC, A. KEMP, A. MACKINNON, A. MACPHEE, Y. PING, R. SHEPHERD, S.C. WILKS, Lawrence Livermore National Laboratory, Livermore, CA, CLIFF CHEN, Massachusetts Institute of Technology, Cambridge, MA, L. ELBERSON, Univ. of Maryland, J. KING, T. MA, F. BEG, Univ. of California, San Diego, R. AKLICLARKE, Central Laser Facility, RAL — The absorption efficiency in laser plasma interactions is of prime importance to the development of fast ignition as a nuclear fusion power source. It has been observed that the coupling of laser energy into targets is a complex process depending on target material, configuration, and laser parameters. Studies were conducted on the Callisto and Titan laser systems at Lawrence Livermore National Laboratory with intensities of up to 10^{20} W/cm^{-2}. Results will be presented for a variety of laser and target parameters.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract DE-FG02-05ER54834, DE-FG02-00ER54606, and W-7405-Eng-48.

GP8.00065 Determination of Electron-Heated Target Temperatures in Petawatt Laser Experiments Using Soft X-Ray Diagnostics[1] , TAMMY MA, FARHAT BEG, University of California-San Diego, ANDREW MACPHEE, HYUN-KYUNG CHUNG, MICHAEL KEY, ANDREW MACKINNON, STEPHEN HATCHETT, Lawrence Livermore National Laboratory, RICHARD STEPHENS, KRAMER AKLI, General Atomics, LINN VAN WOERKOM, The Ohio State University, BINGBING ZHANG, University of California-Davis — The study of the transport of electrons, and the flow of energy into a solid target or dense plasma, is instrumental in the development of fast ignition inertial confinement fusion. Various solid targets (layered foils, cones, wires) were irradiated with the Titan Laser (4x10^{19} Wcm^{-2}) at LLNL. Analysis has been done on soft x-ray images, spectra, and streaked images to determine the thermal electron temperatures on target back surfaces. Three independent methods (Soft X-Ray Spectrometer, 68eV XUV Imager, and 256eV XUV Imager) were used to confirm temperatures, while a fourth diagnostic (Streaked 68eV XUV Imager) provided time-resolved temperature information.

[1]This work was performed under the auspices of the U.S. Dept of Energy by University of CA, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

GP8.00066 Hot Electron Generation Using High Intensity Laser Pulses on Machined Conical Targets[1] , TAKESHI MATSUOKA, STEPHEN REED, STEPAN BULANOV, VLADIMIR CHVYKOV, FOCUS Center and CUOS, University of Michigan, Ann Arbor, Michigan, ANDREI BRANTOV, VALERY BYCHENKOV, Lebedev Physics Institute, Russian Academy of Sciences, Moscow, GALINA KALINCHENKO, CHRISTOPHER MCGUFFEY, PASCAL ROUSSEAU, VICTOR YANOVSKY, FOCUS Center and CUOS, University of Michigan, Ann Arbor, Michigan, DALE LITZENBERG, Department of Radiation Oncology, University of Michigan, Ann Arbor, Michigan, KARL KRUSHELNICK, ANATOLY MAKSIMCHUK, FOCUS Center and CUOS, University of Michigan, Ann Arbor, Michigan — The relative number of the fast electrons has been experimentally measured for a high intensity (4x10^{20}W/cm^2) laser pulse interaction with in situ machined conical aluminum targets. It is shown that the number of electrons and the plasma x-ray signal strongly depends on the cone depth. The cone was laser machined immediately before the 30 TW pulse arrival possibly allowing for a faster, cheaper alternative to traditional conical targets. Particle-in-cell simulations performed for the experimental conditions will be presented. Laser machined conical targets provide a higher laser conversion efficiency into hot electrons.

[1]Supportedby NSF grant PHY-0114336, NIH grant R21CA120262-01

GP8.00067 Implementation of a Stimulated Raman Amplifier/Compressor in Plasma , NIKOLAI YAMPOLSKY, NATHANIEL FISCH, SHUANGLEI LI, VLADIMIR MALKIN, ANATOLI MOROZOV, JUN REN, SZYMON SUCKEWER, ERNEST VALEO, Princeton University, RYAN LINDBERG, JONATHAN WURTELE , UC Berkeley — A plasma-based resonant backward Raman amplifier/compressor for high power amplification of short laser pulses should, in principle, convert almost all of the pump energy to the seed pulse.[1] However, while the theoretically possible efficiency of this scheme has not yet been achieved, accompanied by strong pulse compression larger efficiencies than ever before obtained experimentally are now being reported.[2] These higher experimental efficiencies may be due to favorable compensation between laser parameters, including the chirp of the laser, and the density variations of the mediating plasma. This compensation may extend the region of resonance. The physical mechanisms, which might produce these effects, will be considered in light of the experimental data. This work is supported by DOE grant DE-FG52-07NA28122.

[1]V. M. Malkin, G. Shvets, and N. J. Fisch, Phys. Rev. Lett. 82, 4448 (1999).
[2]J. Ren et al, invited talk, this Bulletin

GP8.00068 X-ray polarization spectroscopy for oblique laser incidence relevant to fast igniter research[1] , Y. OKANO, Y. INUBUSHI, H. NISHIMURA, T. KAI, ILE, Osaka Univ., T. KAWAMURA, Tokyo Tech, D. BATANI, A. MORACE, R. REDAELLI, Univ. Milan, C. FOURMENT, J. SANTOS, G. MALKA, Univ. Bordeaux 1, A. BOSCHERON, A. CASNER, CEA, M. KOENIG, LULI, S. FUJIOKA, T. NAKAMURA, T. JOHZAKI, H. NAGATOMO, M. MIMA, ILE, Osaka Univ. — In a fast ignition study, x-ray polarization spectroscopy is known as one of the useful methods to investigate the velocity distribution function (VDF) of fast electrons in laser plasma, and anisotropy of the VDF has been observed experimentally in previous studies. In this study, we investigated the fast electron transport in intense-laser plasma under oblique incidence. The laser pulse (1 ps, 10 J) was focused onto a polyvinylchloride target at an angle of 67 degrees to the target normal at 10^{18} W/cm^2. It was clearly observed that the resultant Cl-Heα lines for s- or p-polarized laser irradiation differed in polarization. In this presentation, the detail description of fast electron transport will be discussed along with the experimental results.

[1]This work was in part supported by the project on mono-energetic quantum beam science with PW lasers and a Grant-in-Aid for Young Scientists (B) (19740246) from MEXT, Japan.

GP8.00069 X-ray polarization spectroscopy to study energy transport in laser produced plasma at 10^{18} W/cm^2 , H. NISHIMURA, Y. INUBUSHI, Y. OKANO, S. FUJIOKA, T. KAI, ILE, Osaka U., T. KAWAMURA, Tokyo Inst. Tech., D. BATANI, A. MORACE, R. REDAELLI, U. of Milan, Bicocca, C. FOURMENT, J. SANTOS, CELIA, U. Bordeaux 1, G. MALKA, CENBG, U. Bordeaux 1, A. BOSCHERON, CEA/CESTA Le BARP, A. CASNER, CEA-DAM Ile de France, M. KOENIG, LULI, T. NAKAMURA, T. JOHZAKI, H. NAGATOMO, K. MIMA, ILE, Osaka U. — In ultra-high intensity laser produced plasma, velocity distribution function (VDF) of hot electrons is highly anisotropic while that of cold electrons in the bulk plasma is isotropic. X-ray polarization spectroscopy has been used to measure directly VDF of hot electrons in the plasma at 10^{17} W/cm^2 [1, 2]. A new measurement was made at 10^{18} W/cm^2 using Alisé facility at CEA/CESTA. Chlorinated triple-layer targets were irradiated and Cl Heα line was observed with an x-ray polarization spectrometer. Experimental results and comparison with the model prediction will be discussed using a time-dependent atomic kinetics code for polarized Cl Heα radiation [3].
[1] H. Nishimura, et al., *Plasma Phys. Cont. Fusion* **47**, B823 (2005).
[2] Y. Inubushi, et al., JQSRT **99**, 305 (2006); *Phys. Rev.* **E 75**, 026401 (2007).
[3] T.Kai, et al., *Phys. Rev* **A 75**, 012703 (2007), T. Kawamura, et al., submitted.

GP8.00070 Magnetic field effects on moving one-dimensional laser envelope solitons , POORNAKALA SETHURAMAN — Modulated nonlinear structures are formed in the interaction of an intense laser pulse with a plasma where the light energy is trapped by the density cavity. Extensive investigations have been carried out to understand the physics of these solitons. For a circularly polarized light, the electron motion leads to the generation of intense longitudinal magnetic field due to inverse Faraday effects [Sheng and Meyer-ter-Vehn, Phys. Rev. E 54, 1833 (1996)]. The effect of this magnetic field on the coherent structure is an interesting open problem. For a stationary soliton in a magnetized plasma, the trapped electromagnetic energy becomes higher in comparison to the unmagnetized case [Farina et al., Phys. Rev. E 62, 4146 (2000)]. The present study considers the moving structures in a magnetized plasma using relativistic fluid-Maxwell model. The spectral characteristics as well as the stability would be investigated. The study would help qualitatively understand the role of self generated magnetic field on the stability of coherent structures.

GP8.00071 Implications of different stopping power models on target heating simulations using HYDRA[1] , SETH VEITZER, PETER STOLTZ, Tech-X Corporation, JOHN BARNARD, LLNL, ENRIQUE HENESTROZA, LBNL, GARY KERBEL, MARTY MARINAK, LLNL — Accurate numerical simulations of ion driven Warm Dense Matter experiments requires accurate models of stopping powers for targets with temperatures up to a few eV. For finite temperature targets, energy loss of beam ions is comprised of contributions from nuclear stopping, bound electron stopping, and free electron stopping. We compare two different stopping power algorithms and the implications on target heating for two different beams corresponding to the current Neutralized Drift Compression Experiment (NDCX) and proposed NDCX II experiments. The NDCX I beam has a beam energy much lower than the Bragg peak while the NDCX II beam is designed to enter the target just above the Bragg peak, and exit just below. The first stopping power algorithm is based on the classical Bethe-Bloch formulation as is currently implemented in the HYDRA simulation code. The second algorithm is based on rescaling of experimental protonic stopping powers as developed by Brandt and Kitagawa for nuclear and bound electronic stopping, and free electron stopping following the model developed by Peter and Meyer-ter-Vehn.

[1]The work of Tech-X personnel is funded by the Department of Energy under Small Business Innovation Research Contract No. DE-FG02-03ER83797

GP8.00072 Ion beam driven warm dense matter experiments[1] , F.M. BIENIOSEK, P.A. NI, M. LEITNER, P.K. ROY, R. MORE, LBNL, J.J. BARNARD, M. KIREEFF COVO, A.W. MOLVIK, LLNL, H. YONEDA, U. of Electrocommunications, Tokyo, Japan, GSI COLLABORATION — We report plans and experimental results in ion beam-driven warm dense matter (WDM) experiments. Initial experiments at LBNL are at 0.3-1 MeV K+ beam (below the Bragg peak), increasing toward the Bragg peak in future versions of the accelerator. The WDM conditions are envisioned to be achieved by combined longitudinal and transverse neutralized drift compression to provide a hot spot on the target with a beam spot size of about 1 mm, and pulse length about 1-2 ns. The range of the beams in solid matter targets is about 1 micron, which can be lengthened by using porous targets at reduced density. Initial experiments include an experiment to study transient darkening at LBNL; and a porous target experiment at GSI heated by intense heavy-ion beams from the SIS 18 storage ring. Further experiments will explore target temperature and other properties such as electrical conductivity to investigate phase transitions and the critical point.

[1]This work performed under U.S DOE contracts W-7405-Eng-48 and DE-AC02-05CH11231.

GP8.00073 Diagnostics for heavy ion beam driven Warm-dense-matter experiments.[1] , PAVEL NI, FRANK BIENIOSEK, MATTHAEUS LEITNER, WILLIAM WALDRON, Lawrence Berkeley National Laboratory — Intense heavy ion beams are an excellent tool to create large-volume samples of warm-dense-matter (WDM) with fairly uniform physical conditions. An extensive WDM experimental program is scheduled at LBNL where NDCX accelerator is used as a driver for heating metallic targets. This poster will focus on designing and implementation of diagnostics for a target. The diagnostics include a fast multi-channel optical pyrometer, absolutely calibrated streak camera-based spectrometer, Doppler-shift laser interferometer (VISAR) and fast gated CCD cameras. This equipment is capable of precise measurement of temperature starting from 2000 K, pressure in kbar region, and expansion velocities up to several km/sec. Temporal resolution of the diagnostic is on a sub-nanosecond time scale.

[1]This work performed under the auspices of the U.S Department of Energy by University of California, Lawrence Berkeley National Laboratory under contracts No. DE-AC02-05CH11231.

GP8.00074 Measurement of ultra-fast material dependent heating from solid foils in high-intensity laser-plasma interaction experiments[1] , R.L. WEBER, E. CHOWDHURY, R.R. FREEMAN, J. MORRISON, L. VAN WOERKOM, The Ohio State University, E. GARCIA SAIZ, F. KHATTAK, D. RILEY, Queens University Belfast, S. ROSE, Imperial College, S. GLENZER, S. HANSEN, S. WILKS, LLNL, B. BARBREL, M. KOENIG, LULI, A. PELKA, M. ROTH, T.U. Darmstadt, R.J. CLARKE, M. NOTLEY, D. NEELY, RAL, G. GREGORI, University of Oxford and RAL — Ultra-fast material dependent radiative heating of dense matter was observed at the Vulcan 100 TW laser facility at RAL (UK). These processes are driven by the transport of fast electrons which isochorically heat the solid at temperatures where radiative processes may become important. The peak laser intensity on target was $\sim 10^{19}$ W/cm^{-2} for irradiation of 200 μm square solid foils consisting of PVDC sandwiched between either 1 μm Au, CH, or Al to study differences between high and low Z materials in the radiation drive. Characteristic x-ray emission from Cl was analyzed using time resolved and time integrated graphite Bragg crystals, as well as an XUV spectrometer. The plasma expansion at the rear of the target was monitored with a pinhole camera. Numerical simulations of the characteristic Cl emission have been used to infer the plasma conditions in the target.

[1]Supported by the STFC (UK) and DOE DE-FG-02-05ER54834.

GP8.00075 DIVERTORS, EDGE PHYSICS AND FUELING —

GP8.00076 Generation mechanisms of blobs in tokamak edge plasmas. , KOWSIK BODI, SERGEI KRASHENINNIKOV, UCSD, ANDREI SMOLYAKOV, University of Saskatchewan — Meso-scale structures, driven by curvature and gradB effects, like blobs and ELMs play a very important role in edge and SOL plasma transport in tokamaks. Once these meso-scale structures formed, they exhibit clear convective behavior propagating mainly toward the wall at low B-field side of the torus. The main features of convection mechanisms are relatively well understood. It is widely believed that generation of ELMs is triggered by peeling-ballooning instability. But, the mechanism (-s) and the rate of blob generation are not clear yet. Here we present both analytic and modeling results describing the mechanisms of the blob generation triggered by sub-critical phenomena related to the ballooning drive.

GP8.00077 Linear Analysis and Verification Suite for Edge Turbulence[1] , J.R. MYRA, D.A. D'IPPOLITO, D.A. RUSSELL, Lodestar Research Corp., M. UMANSKY, LLNL — Tokamak edge physics research is becoming increasingly reliant on large-scale plasma simulation. The accuracy and reliability of software codes must be insured through rigorous verification and validation. Kinetic edge physics simulation codes such as those being developed under the ESL and CPES projects could benefit from standardized benchmarks. Measurement of the linear growth rate of unstable modes emerging from a known, established equilibrium configuration provides one of the few quantitative ways of rigorously benchmarking turbulence codes with each other and with a universal standard. The present paper discusses the proposed development of a community-standard suite of edge instability codes for linearized, nonlocal (e.g. separatrix-spanning) modes in axisymmetric (realistic divertor), toroidal geometry. The suite will consist of a new eigenvalue code, as well as the recently revised BOUT code, and will be geared to provide a community-wide benchmarking/verification tool for nonlinear edge plasma simulations. Initial progress will be reported.

[1]Supported by the USDOE under grant DE-FG02-07ER84718.

GP8.00078 Calculation of ion distribution functions and neoclassical transport in the edge of single-null divertor tokamaks[1] , T.D. ROGNLIEN, R.H. COHEN, X.Q. XU, LLNL — The ion distribution function in the H-mode pedestal region and outward across the magnetic separatrix is expected to have a substantial non-Maxwellian character owing to the large banana orbits and steep gradients in temperature and density. The 4D (2r,2v) version of the TEMPEST continuum gyrokinetic code is used with a Coulomb collision model to calculate the ion distribution in a single-null tokamak geometry throughout the pedestal/scrape-off-layer regions. The mean density, parallel velocity, and energy radial profiles are shown at various poloidal locations. The collisions cause neoclassical energy transport through the pedestal that is then lost to the divertor plates along the open field lines outside the separatrix. The resulting heat flux profiles at the inner and outer divertor plates are presented and discussed, including asymmetries that depend on the B-field direction. Of particular focus is the effect on ion profiles and fluxes of a radial electric field exhibiting a deep well just inside the separatrix, which reduces the width of the banana orbits by the well-known squeezing effect.

[1]Work performed under auspices of US DOE by UC LLNL under contract No. W-7405-ENG-48.

GP8.00079 Implementation of an anomalous radial transport model for continuum kinetic edge codes[1] , K. BODI, S.I. KRASHENINNIKOV, UCSD, R.H. COHEN, T.D. ROGNLIEN, LLNL, ESL TEAM — Radial plasma transport in magnetic fusion devices is often dominated by plasma turbulence compared to neoclassical collisional transport. Continuum kinetic edge codes [such as the (2d,2v) transport version of TEMPEST and also EGK] compute the collisional transport directly, but there is a need to model the anomalous transport from turbulence for long-time transport simulations. Such a model is presented and results are shown for its implementation in the TEMPEST gyrokinetic edge code. The model includes velocity-dependent convection and diffusion coefficients expressed as a Hermite polynominals in velocity. The specification of the Hermite coefficients can be set, e.g., by specifying the ratio of particle and energy transport as in fluid transport codes. The anomalous transport terms preserve the property of no particle flux into unphysical regions of velocity space. TEMPEST simulations are presented showing the separate control of particle and energy anomalous transport, and comparisons are made with neoclassical transport also included.

[1]Work performed under auspices of US DOE by UC LLNL under contract No. W-7405-ENG-48.

GP8.00080 Simulation of turbulence in tokamak edge plasmas[1] , M.V. UMANSKY, LLNL, J. BOEDO, UCSD, B. LABOMBARD, MIT, R. MAQUEDA, Nova Photonics, J. TERRY, MIT, S. ZWEBEN, PPPL — We undertake a comparative computational study of edge plasma turbulence in tokamaks. Some, perhaps much, of the physics underlying edge turbulence in existing tokamak experiments can be captured by fluid equations for collisional plasma, however due to the complexity of the problem in most cases one has to rely on numerical simulations. Applying electromagnetic fluid turbulence code BOUT to tokamak edge plasmas we generally find consistency with experimentally known cross-field spatial structure of the N_i fluctuations having characteristic scale on the order of a few cm. Coherent structures moving radially at a speed of a few km/s are also consistent with many experimental observations. However, the numerical results can be sensitive to details of physics model, choice of parameters, and geometry options. Certain parameters are not well known experimentally and thus can serve as free "dialing knobs," e.g. effective ion charge, Z_{eff}, and radial electric field, E_r, at the core boundary. Simulation results and comparative analysis for edge plasmas in Alcator C-Mod, NSTX, and DIII-D will be presented.

[1]Work performed for USDOE by Univ. Calif. LLNL under contract W-7405-ENG-48.

GP8.00081 Kinetic XGC0 study of the 3D resonance magnetic perturbation effect on edge pedestal dynamics and the ELM onset boundary , GUNYOUNG PARK, S. KU, C.-S. CHANG, H. STRAUSS, New York University, I. JOSEPH, R. MOYER, University of California at San Diego, P. SNYDER, General Atomics, CPES TEAM — Effect of the resonance magnetic field perturbation (RMP) on the edge pedestal dynamics is studied using an edge particle code XGC0. Its impact on the stability boundary of the edge localized modes (type-I ELM) is examined by coupling XGC0 to the linear ideal MHD code Elite. Reduction of the pedestal density by RMP is explained for the first time, with increased ion temperature. The electron temperature can rise if sufficient heat can flow out from the core into the edge. In addition to the pressure profile changes in an unconventional way, the bootstrap current profile can also change in an unconventional way in the presence of RMP. Thus, RMP can modify the MHD stability property of the edge localized mode. XGC0 is a full-f, edge guiding center particle code which has a realistic magnetic field geometry with a radial electric field solver. XGC0 can include 3D magnetic perturbation, magnetic separatrix, material wall with neutral recycling, Monte Carlo neutral particles with atomics, and ions and electron particles with conserving collisions.

GP8.00082 Effects of Elongation on Stochastic Layer and Magnetic Footprint in Divertor Tokamaks , HASINA WADI, MORGIN JONES, HALIMA ALI, ALKESH PUNJABI, Center for Fusion Research and Training, Hampton University, Hampton, VA 23668 — An area-preserving map is constructed to calculate effects of elongation on the stochastic layer and magnetic footprint in divertor tokamaks. The generating function for the map is $S(x,y) = -(1/2)\alpha^2 y^2 (1-y^2/2a^2)+(1/2)\beta^2 x^2$. Method of maps developed by Punjabi and Boozer [1,2] is used to construct the map and to calculate the stochastic layer and the magnetic footprints. The poloidal magnetic flux inside the ideal separatrix and the safety factor profile are held constant, and elongation is varied by (1) varying the width of separatrix surface in the midplane keeping the height fixed, and (2) varying the height keeping the width of separatrix surface fixed. As the width is increased, the stochastic layer and the footprint become narrower. As the height is increased, the width of stochastic layer and the footprint become narrower. Detailed results of this study will be presented. This work is supported by US DOE OFES DE-FG02-01ER54624 and DE-FG02-04ER54793.

[1] A. Punjabi, A. Verma, and A. Boozer, *Phys Rev Lett*, **69**, 3322-3325 (1992).
[2] A. Punjabi, H. Ali, T. Evans, and A. Boozer, *Phys Lett A* **364** 140–145 (2007).

GP8.00083 The DIII-D Map – An Area-Preserving Map for Trajectories of Magnetic Field Lines in the DIII-D Tokamak , ALKESH PUNJABI, HALIMA ALI, Center for Fusion Research and Training, Hampton University, Hampton, VA 23668, ALLEN BOOZER, Columbia University, New York, NY 10027, TODD EVANS, General Atomics, San Diego, CA 92186 — The EFIT data for the DIII-D shot 115467 3000 ms is used to calculate the generating function for an area-preserving map for trajectories of magnetic field lines in the DIII-D. We call this map the DIII-D map. The generating function is a bivariate polynomial in base vectors $\psi^{1/2}\cos(\theta)$ and $\psi^{1/2}\sin(\theta)$. ψ is toroidal flux and θ is poloidal angle. The generating function is calculated using a canonical transformation from (ψ,θ) to physical coordinates (R,Z) in the DIII-D [1] and nonlinear regression. The equilibrium generating function gives an excellent representation of the equilibrium flux surfaces in the DIII-D. The DIII-D map is then used to calculate effects of the magnetic perturbations in the DIII-D. Preliminary results of the DIII-D map will be presented. This work is supported by US DOE OFES DE-FG02-01ER54624 and DE-FG02-04ER54793.

[1] A. Punjabi, H. Ali, T. Evans, and A. Boozer, *Phys Lett A* **364** 140–145 (2007).

GP8.00084 Canonical Representations of the Simple Map

, OLIVIA KERWIN, ALKESH PUNJABI, HALIMA ALI, Center for Fusion Research and Training, Hampton University, Hampton, VA 23668, ALLEN BOOZER, Columbia University, New York, NY 10027 — The simple map is the simplest map that has the topology of a divertor tokamak. The simple map has three canonical representations: (i) toroidal flux and poloidal angle (ψ,θ) as canonical coordinates, (ii) the physical variables (R,Z) or (X,Y) as canonical coordinates, and (iii) the action-angle (J,ζ) or magnetic variables (Ψ,Θ) as canonical coordinates. We give the derivation of the simple map in the (X,Y) representation. The simple map in this representation has been studied extensively (Ref. 1 and references therein). We calculate the magnetic coordinates for the simple map, construct the simple map in magnetic coordinates, and calculate generic topological effects of magnetic perturbations in divertor tokamaks using the map. We also construct the simple map in (ψ,θ) representation. Preliminary results of these studies will be presented. This work is supported by US DOE OFES DE-FG02-01ER54624 and DE-FG02-04ER54793.

[1] A. Punjabi, H. Ali, T. Evans, and A. Boozer, *Phys Lett A* **364** 140–145 (2007).

GP8.00085 Second Order Magnetic Barriers in Tokamaks, Noble Tori, and Topological Noise

, HALIMA ALI, ALKESH PUNJABI, Center for Fusion Research and Training, Hampton University, Hampton, VA 23668 — Second order perturbation method of creating invariant manifold inside chaos in Hamiltonian systems [1-4] is applied to tokamak to build magnetic barriers inside the region of magnetic chaos created by resonant magnetic perturbations. Different safety factor profiles are used to represent tokamaks such as the ohmically heated tokamaks (OHT), the DIII-D and the ASDEX UG. In OHT, a magnetic barrier is created at about midway between two resonant magnetic surfaces. The barrier reduces the diffusion of magnetic field lines by about half. The barrier is fortified by adding up to third order magnetic perturbation. Beyond a maximum value of magnetic perturbation, the barrier is not sustainable. However, if a barrier is created at noble value of safety factor, then it is found to be much more robust. For the DIII-D, the robustness of magnetic barrier is tested for topological noise, and the barrier is found to be robust up to some maximum value of noise. This work is supported by US DOE OFES DE-FG02-01ER54624 and DE-FG02-04ER54793.

[1] Ciraolo G *et al.* 2004, *J. Phys. A: Math Gen* **37** 3589.
[2] Ciraolo G *et al.* 2004, *Phys. Rev. E* **69** 056213.
[3] Vittot M 2004, *Phys. A: Math Gen* **37** 6337.
[4] Chandre C *et al.* 2005, *Phys. Rev. Lett.***94** 074101.

GP8.00086 H-mode edge physics in NSTX and Alcator C-Mod

, F. KELLY, R. MAQUEDA, Nova Photonics, R. MAINGI, Oak Ridge National Laboratory, AND THE NSTX TEAM — In NSTX (National Spherical Torus Experiment), ELMs (Edge Localized Modes) are observed using a fast-framing camera to interact with an inner-wall MARFE (Multi-faceted Asymmetric Radiation From the Edge), leading to partial burn-through of the MARFE during the ELM cycle [1]. We reexamine the MARFE stability [2] to attempt an explanation of the MARFE/ELM dynamics in NSTX. The contribution of ion self-diffusion [3,4] to the radial electric field is estimated for an L-H transition in Alcator C-Mod.

[1] R. Maqueda, et al., Bull. Am. Phys. Soc., **51**(7), 237 (2006);
[2] F. Kelly, et al., Bull. Am. Phys. Soc. **51**(7), 237 (2006);
[3] A. Simon, Phys. Rev. **100**, 1557 (1955);
[4] C. L. Longmire and M. N. Rosenbluth, Phys. Rev., **103**, 507 (1957).

GP8.00087 Recent results on ELM-like plasma-surface interactions produced by a conical theta-pinch

, TRAVIS GRAY, MICHAEL WILLIAMS, DAVID RUZIC, University of Illinois at Urbana-Champaign, ISAK KONKASHBAEV, Argonne National Laboratory, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM, ARGONNE NATIONAL LABORATORY TEAM — The Divertor Erosion and Vapor shielding eXperiment (DEVeX) at the University of Illinois at Urbana-Champaign is designed to produce plasmas with densities on the order of 10^{21} m^{-3} with a total plasma temperature of several hundred eV. This is accomplished with the rapid discharge of a 64 kJ capacitor bank through a conical shaped θ-pinch coil. The general purpose of the facility is to generate energetic plasma flows to study plasma-material interaction relevant to disruption conditions in TOKAMAKs. However, the facility has been designed with great flexibility to be able to study high power, pulsed electric propulsion; FRC formation and translation; and relevant astro-physical plasma jets. Here, the first measurements of the plasma flow and translation from the θ-pinch are presented. A theoretical model is also shown to predict how these energetic plasma flows will interact with solid materials. This work is important to understanding the ultimate plasma facing component (PFC) lifetime and viability. It also provides an opportunity to measure plasma/vapor cloud formation and interaction with an incident flowing plasma.

GP8.00088 Divertor and confinement issues for next-step devices.[1]

, MICHAEL KOTSCHENREUTHER, PRASHANT VALANJU, SWADESH MAHAJAN, Institute for Fusion Studies — Next step devices operating in advanced tokamak (AT) modes include proposed experiments (including NHTX and FDF), Component Test Facilities (CTFs), and ITER. We present an analysis of the likely scrape-off layer widths and heat loads on the divertors for such devices. We include analysis of novel divertor configurations including X-divertors and stochastic edge. The connection between divertor modifications and core plasma confinement is also examined.

[1] Work supported by DOE Grant DE-FG02-04ER54742, and by ICC Grant DE-FG02-04ER54754.

GP8.00089 T_e and n_e profile measurements with HRTS during ELM mitigation experiments with external magnetic perturbation fields on JET

, ROBERTO PASQUALOTTO, ALBERTO ALFIER, Consorzio RFX, Italy, MARC BEURSKENS, MARK KEMPENAARS, CLAIRE MCKENNA, Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, UK, EDMONDO GIOVANNOZZI, ENEA, Italy, RUDI KOSLOWSKI, YUNFENG LIANG, FZJ, Germany, AND EFDA-JET CONTRIBUTORS TEAM[1] — In recent experiments on JET, type-I ELMs in H-mode plasmas have been controlled by a set of 4 error field correction coils (EFCC) which externally generate magnetic perturbation field with toroidal mode numbers n=1 or n=2. The effect of this perturbation on T_e and n_e profiles has been studied with the High Resolution Thomson Scattering (HRTS) which has recently become operative on JET. The EFCCs effect on ELMs has been investigated in various plasma configurations with different directions of the perturbation field and mode numbers. The edge pedestal barrier is modified in different ways, depending on the configuration. In all cases, ELM mitigation correlates with a reduction of the edge pressure gradient due to a reduced height and an increased width of the edge pressure transport barrier.

[1] see the Appendix of M L Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA (2006).

GP8.00090 Two-dimensional structure of volume recombination in JT-60U detached divertor plasmas , FUJIMOTO KAYOKO, NAKANO TOMOHIDE, KUBO HIROTAKA, Japan Atomic Energy Agency, SAWADA KEIJI, Shinshu University, TAKIZUKA TOMONORI, KAWASHIMA HISATO, SHIMIZU KATSUHIRO, ASAKURA NOBUYUKI, Japan Atomic Energy Agency — The volume recombination in detached divertor plasmas is a key process to reduce the ion flux to the divertor plates. Two-dimensional measurement is one of the ways to investigate a spatial structure of the volume recombination. In this work, the deuterium Balmer-series lines (D_α, D_β, ..., D_θ) from a detached divertor plasma were observed two-dimensionally with a spatial resolution of $\sim$ 1 cm and were reconstructed into two-dimensional emissivities with a tomography technique. The ratio of the D_β to the D_α emissivity was compared to that calculated by the collisional-radiative model. This ratio could not be explained only by the excitation of D by electron impact, indicating that the volume recombination contributed to the D_β emission. This is the case for the region above the inner strike point with $\sim$ 8 cm and $\sim$ 4 cm, respectively, in the r- and the z-direction on the poloidal cross-section. In this region, from the ratios of the D_α, D_β, ..., D_θ emissivities, the electron density and temperature were evaluated to be $\sim$ 1E20 m^{-3} and < 0.3 eV, respectively.

GP8.00091 Flute instability in the divertor plasma , D.D. RYUTOV, R.H. COHEN, Lawrence Livermore National Laboratory, Livermore, CA 94551 — An analysis of the flute instability in the realistic geometry of an X-point divertor is provided, for both common and private flux regions. The drive includes curvature and the electron temperature gradient, combined with the sheath boundary condition at the divertor plates. The effects of X-point shearing, that have been in the past described in a semi-phenomenological manner, are included based on first principles. The curvature drive is shown to be significant for both inner and outer divertor legs, contrary to the slab analysis. Characteristic signatures of the ensuing instabilities (typical frequencies, wave-numbers, correlation between the density and potential perturbations) are presented. The effects of the sheath boundary conditions on the instabilities are explicitly displayed. The results can be used for the interpretation of experiments and for code benchmarking. Work performed for US DOE by UC LLNL under contract No. W-7405-Eng-48.

GP8.00092 Effect of High Recycling Step-Wise Migration on ITER Co-deposition[1] , JIM STRACHAN, Plasma Physics Lab, Princeton University — In the modeling of the JET ^{13}C migration experiments [1], step wise migration of the ^{13}C along the outer target was postulated to explain the lack of ^{13}C deposits on the outer target. The consequence was deposits were created by neutral carbon transport into the Private Flux Region. Some of that deposit can be eroded by neutral deuterium emission from the inner and outer strike points. Also important is the effect of the $\underline{\mathbf{E}}\times\underline{\mathbf{B}}$ force on migration from the outer strike point to the inner strike point since the $\underline{\mathbf{E}}\times\underline{\mathbf{B}}$ force can be high in the Private Flux Region. In this paper, these effects will be estimated for the ITER divertor. In particular the step wise migration of tungsten from the W/C intersection on the divertor should cause higher C erosion. The carbon itself will also undergo the stepwise migration causing the eroded carbon to preferentially migrate to the Private Flux Region as neutrals and to suffer further erosion by neutral hydrogenic bombardment.
[1] J.D.Strachan, *et al*, EPS Conference on Plasma Physics (Warsaw, 2007) paper P1.030

[1]Supported by DOE

GP8.00093 Initial results from Langmuir probe and thermal desorption spectroscopy (TDS) measurements in the Tritium Plasma Experiment (TPE) , MASASHI SHIMADA, PHIL SHARPE, Idaho National Laboratory, ROBERT KOLASINSKI, RION CAUSEY, Sandia National Laboratories — The Tritium Plasma Experiment (TPE) has been recently relocated from Los Alamos National Laboratory (LANL) to Safety and Tritium Applied Research (STAR) facility in Idaho National Laboratory (INL). The application of a Langmuir probe system, newly designed target holder, and thermal desorption spectroscopy (TDS) system were successfully carried out, and the initial results from Langmuir probe measurements in deuterium plasma and TDS measurements of deuterium retention in tungsten are discussed. TPE is now ready to provide data to the fusion community on the interaction of tritium plasma with plasma facing components, and the future research plan is discussed.

GP8.00094 MHD THEORY, HEATING AND CURRENT DRIVE —

GP8.00095 Theory of Intermediate Nonlinear Ballooning Mode in a Tokamak[1] , P. ZHU, C.C. HEGNA, University of Wisconsin-Madison — In this work we extend the ideal MHD theory of intermediate nonlinear ballooning instabilities [2] to the case of tokamak plasmas. Evolution equations for plasma displacements induced by the ballooning instability are analytically derived that account for the dominant nonlinear effects in an ideal MHD description. The intermediate nonlinear regime of ballooning modes is defined by the ordering that the plasma displacement (ξ_Ψ) across field line in the direction of pressure gradient is comparable to the mode width (l_Ψ) in the same direction. In the tokamak case, this regime becomes particularly relevant for a transport barrier as the width of that barrier (or pedestal) region approaches the width (l_Ψ) of the dominant ballooning mode.

[1]Research supported by U.S. DOE grant No. DE-FG02-86ER53218.
[2]P. Zhu and C. C. Hegna, Sherwood 2007.

GP8.00096 Unified theory of resistive and inertial ballooning modes in three-dimensional configurations[1] , TARIQ RAFIQ, CHRIS C. HEGNA, JAMES D. CALLEN, University of Wisconsin — A linear stability theory of non-ideal MHD ballooning modes is investigated using a two fluid model. Electron inertia, diamagnetic effects, parallel ion dynamics, transverse particle diffusion and perpendicular viscous stress terms are included in calculations for arbitrary three-dimensional electron ion plasmas. Drift RBM eigenvalues and eigenfunctions are calculated for a variety of equilibria including axisymmetric shifted circular geometry and configurations of interest to the Helically Symmetric Stellarator (HSX). For parameters of interest to HSX, characteristic growth rates exceed the electron collision frequency. In this regime, electron inertia effects can dominate plasma resistivity and produce an instability whose growth rate scales with the electron skin depth. Attempts to generalize previous analytic calculations of RBM stability using a two scale analysis on $(s-\alpha)$[1] equilibria to more general 3-D equilibria will be addressed. In this work, a unified theory of RBM and inertial ballooning modes is developed where both the effects of ideal MHD energy and geodesic curvature drives in the non-ideal layer are included in the dispersion relation. [1] R. H Hastie, J.J. Ramos and F. Porcelli *Phys. Plasmas* **10,** 4405 (2003).

[1]Supported by U.S. DoE under DE-FG02-99E54546 and DE-FG02-86ER53218.

GP8.00097 Stabilization of the Vertical Mode in Tokamaks by Localized Nonaxisymmetric Fields[1] , ALLAN REIMAN, Princeton Plasma Physics Laboratory, Princeton University, Princeton, NJ — We find that vertical instability of tokamak plasmas can be controlled by nonaxisymmetric magnetic fields localized near the plasma edge at the bottom and top of the torus, and that the required magnetic fields can be produced by a relatively simple set of parallelogram-shaped coils. By providing stable equilibria with more highly elongated cross-sections, the addition of these nonaxisymmetric fields can potentially lead to devices with improved confinement and/or beta limits. The analytical calculation assumes a large aspect ratio plasma that is well approximated by a cylinder, $\beta = 0$, and a uniform equilibrium current density. Stability is determined by a δW calculation, using the stellarator approximation [1] for both the equilibrium and stability calculations. The physical mechanism of the stabilization suggests that the stability properties do not depend on the precise shape of the coils, so that curvature can be introduced to optimize relative to other considerations.
[1] J. Greene and J. Johnson, Phys. Fluids **4**, 875 (1961); J. Johnson and J. Greene, Phys. Fluids **4**, 1417 (1961).

[1]This work was supported by DOE contract DE-AC02-76CH03073.

GP8.00098 Studies of ELMs and RMPs with M3D[1] , H.R. STRAUSS, BERNHARD HIENTZSCH, G.Y. PARK, C.S. CHANG, NYU, L. SUGIYAMA, MIT — Several recent applications of M3D are presented. Studies are in progress in the penetration of resonant magnetic perturbations (RMP) which have been found to stabilize edge localized modes (ELM). In a two fluid MHD model, RMPs did not provide ELM stabilization in studies conducted so far. Instead the plasma relaxes toward a 3D equilibrium. The ELM stabilization evidently comes from kinetic modification of the pressure and current profiles. Simulations with the XGC kinetic neoclassical code suggest that RMPs are screened from the plasma. Calculation of screening caused by plasma rotation is in progress. In other work, ELM benchmarking simulations will be be presented. In linear simulations, M3D, NIMROD, and ELITE were found to be in reasonable agreement. Preliminary application of spectral elements to ELM simulations will be presented.

[1]supported by USDOE.

GP8.00099 Kinetic Effects of a Non-Maxwellian Distribution of Energetic Particles on 2/1 Stability[1] , R. TAKAHASHI, D.P. BRENNAN, University of Tulsa, C.C. KIM, University of Washington, A.D. TURNBULL, R.J. LA HAYE, General Atomics — Recent experiments have shown JET discharges to be stable for values of $\beta_N/4\ell_I$ as a function of ρ^* far exceeding where JT-60U, DIII-D, and ASDEX-U are unstable. It is conjectured that kinetic effects of energetic particles can play a crucial role in the stability of the 2/1 mode in JET. Using model equilibria based on experimental reconstructions, the non-ideal MHD stability and nonlinear evolution of the 2/1 mode is investigated including a delta-f PIC model for the energetic particles coupled to the MHD solution. Modifications of the ideal outer region solution of linear resistive MHD codes are discussed, along with preliminary results from initial value computations.

[1]Supported by US DOE Grant DE-FG02-07ER54931

GP8.00100 Reduced energy principle for ideal/tearing modes in separatrix limited plasmas[1] , JOSHUA KALLMAN, Princeton University, LEONID ZAKHAROV, PPPL — Ideal and tearing MHD modes near the edge of a plasma represent a significant threat to plasma stability, confinement, and plasma facing material surfaces. Theoretical and numerical studies of these modes are extremely difficult due to the presence of a magnetic separatrix and the multiple resonance surfaces inside it. In this presentation, we examine an exceptional case in which the MHD energy principle can be reduced to the minimization of a line integral functional instead of a complicated 2-D expression, thereby avoiding numerical convergence problems. In addition, a numerical implementation of Bishop-Taylor equilibria, a special class of toroidal equilibria in which a unique set of magnetic flux surfaces can be determined by infinitely many pressure and current profiles, is discussed. Due to this indeterminacy, such equilibria are of great use in calibrating equilibrium codes, and can additionally contain a separatrix region, which makes them especially relevant for the stability analysis outlined above.

[1]Supported by US DOE Contract No.DE-AC020-76-CHO-3073

GP8.00101 A general MHD stability formulation for plasmas with flow and resistive walls , JEFFREY FREIDBERG, LUCA GUAZZOTTO, Masschusetts Institute of Technology, RICCARDO BETTI, University of Rochester — Plasma rotation, induced either by means of neutral beams (e.g. in NSTX and DIII-D) or appearing spontaneously (e.g. in Alcator C-Mod, JET and Tore Supra) is routinely observed in modern tokamak experiments. Plasma rotation has a major effect on plasma stability. In particular, flow and flow shear stabilize external modes such as the resistive wall mode (as observed e.g. in DIII-D), and also have a significant influence on turbulence, internal kinks and ballooning modes. A self-consistent analysis of the effect of rotation requires the use of numerical tools. In this work, we extend our previous analysis and present a general *variational* eigenvalue formulation of the stability problem. The analysis includes arbitrary (both toroidal and poloidal) plasma rotation and a thin resistive wall of arbitrary shape and resistivity. It is shown the problem can always be reduced to a classic eigenvalue formulation of the kind $i\omega\mathbf{A}\cdot\zeta=\mathbf{B}\cdot\zeta$, where ζ is the unknown eigenvector related to the plasma displacement, and ω the (complex) evolution frequency of the perturbation. The formulation is well suited for a finite element analysis.

GP8.00102 A Model for Coupled Turbulence and Resistive MHD Evolution[1] , D.P. BRENNAN, University of Tulsa, C. HOLLAND, University of California San Diego, R. TAKAHASHI, University of Tulsa — The development of a coupled three field turbulence and resistive MHD mode theory is investigated. The effects of turbulence are known to be important in the evolution of MHD instabilities, and the modifications to the background equilibrium by the MHD instabilities are known to affect turbulent fields. Our initial investigations focus on the effects of turbulence on the linear resistive MHD stability of an unstable equilibrium in slab geometry, as well as the effects of the concomitant finite magnetic island structure on the local turbulent fields. Analytic descriptions are presented of the turbulent resistivity and viscosity, and MHD instability criteria in this equilibrium. Results are then presented of the turbulent fields and linear growth rates in the presence of the island. Both resistive Alfven wave and drift wave turbulence are addressed. Finally, preliminary results are presented from an initial value code modeling the turbulence, which will be coupled to the nonlinear MHD evolution of the island.

[1]Supported by US DOE Grant DE-FG02-07ER54931

GP8.00103 Extending the collisional fluid equations into the long mean-free-path regime in toroidal plasmas. IV. Banana Regime , K. SHAING, Plasma and Space Science Center, National Cheng Kung University — In Part I [Phys. Fluids B **2**, 1190 (1990)] and Part II [Phys. Plasmas **12**, 082508 (2005)], it is emphasized that the equilibrium plasma viscous forces when applied for the magneto-hydrodynamic (MHD) modes are only rigorously valid at the mode rational surface where $m - nq = 0$. Here $m$is the poloidal mode number, n is the toroidal mode number, and q is the safety factor. This important fact has been demonstrated explicitly by calculating the viscous forces in the plateau regime in Part I, and II. Here, the effective viscous forces in the banana regime are calculated for MHD modes by solving the linear drift kinetic equation that is driven by the plasma flows first derived in Part I. At the mode rational surface, the equilibrium plasma viscous forces are reproduced. However, it is found that away from the mode rational surface, the viscous forces for MHD modes decrease, a behavior similar to that observed in the viscous forces for the plateau regime. The proper form of the momentum equation that is appropriate for the modeling of the MHD modes is also discussed.

GP8.00104 A family of analytic equilibrium solutions for the Grad-Shafranov equation. , LUCA GUAZZOTTO, JEFFREY FREIDBERG, Massachusetts Institute of Technology — In toroidal systems, such as the tokamak, magnetohydrodynamic equilibria are routinely described by means of the well known Grad-Shafranov (GS) equation. Analytic solutions of the equation are few and far between, and equilibria are normally determined with the help of numerical tools. Even though equilibrium codes are nowadays very reliable, it is still worthwhile to investigate the existence of analytic solutions of the GS equation, because (1) such equilibria are very useful in providing benchmark cases to test existing codes, (2) analytic solutions provide a good model to test for stability without having to worry about accuracy and resolution issues arising from numerically computed equilibria. In this work, we present a technique to solve the GS equation for special, but realistic, profiles of the two free functions of magnetic flux. Our solution allows us to retain arbitrary plasma elongation and triangularity, arbitrary aspect ratio, and arbitrary beta, while setting the edge current and pressure gradient to zero. We show that realistic equilibria for standard (e.g. ITER, C-MOD) and spherical (e.g. NSTX) tokamaks can be obtained with our technique.

GP8.00105 Free boundary three-dimensional anisotropic pressure equilibria , W.A. COOPER, J.P. GRAVES, M. JUCKER, Ecole Polytechnique Federale de Lausanne CRPP, Association Euratom-Suisse, Lausanne, Switzerland, S.P. HIRSHMAN, Oak Ridge National Laboratory, Oak Ridge TN, J. KISSLINGER, P. MERKEL, H. WOBIG, Max Planck Institut fuer Plasma Physik, Garching, Germany, Y. NARUSHIMA, S. OKAMURA, K.Y. WATANABE, National Institute for Fusion Science, Toki, Japan — An anisotropic pressure model for three-dimensional magnetohydrodynamic equilibria with nested magnetic flux surfaces has been implemented in a free boundary version of the VMEC code. The energetic particles are described with a modified Bi-Maxwellian distribution function that satisfies the constraint $\mathbf{B} \cdot \nabla \mathcal{F}_h = 0$. Applications to 2-field period quasiaxisymmetric stellarator reactor system at large $\langle\beta\rangle \sim 5\%$ with large pressure anisotropy and off-axis hot particle deposition have been explored to test the limits of the code. The hot particle pressure distributions reproduce the structures previously obtained under fixed boundary conditions. For example, for $p_\perp > p_{||}$ and high field side hot particle deposition, the $p^h_\perp$ distribution localises also on the high field side contrary to the $p^h_{||}$ structure which concentrates on the low field side. For low field side deposition, both hot particle components appear on the low field side. A radially outward shift of the entire plasma column constitutes the dominant finite $\langle\beta\rangle$ effect. Plasma shape alterations are also observable.

GP8.00106 An Optimal Magnetic Coordinate system for High-Beta ST configurations[1] , JANARDHAN MANICKAM, Princeton Plasma Physics Laboratory — In the study of magnetohydrodynamics of magnetically confined systems, it is well known that both analysis and computation are facilitated by an appropriate coordinate system. Specifically, a magnetic coordinate system,(Ψ, θ, ζ),where Ψ is a flux label, θ a poloidal angle and ζ a generalized toroidal angle, such that magnetic field lines are straight in (θ, ζ) space. The generalized toroidal angle, ζ, can be related to the Cartesian angle ϕ, by introducing a periodic function $\delta(\Psi, \theta)$. This function depends on the choice of Jacobian, and is identically zero when the Jacobian is proportional to x^2. This coordinate is commonly referred to as PEST coordinates. A more general approach to straight field line coordinates is obtained when the Jacobian is defined as $J = X^i/\alpha(\Psi)|\nabla\dot{\Psi}|^j$. Commonly used coordinate systems are: PEST, with i=2 , j=0; Equal Arcs, with i=j=1; and Hamada with i=j=0. Each of these coordinates has its own merits, but for high beta spherical tori, we identify a new coordinate system, i=0, j=1, which is optimal to this regime. We present results comparing the different coordinate systems in different parameter regimes.

[1]This work was supported by DoE Contract No. DE-AC02-76-CHO-3073.

GP8.00107 3DMAPTOR Code for mapping toroidal magnetic field lines in three dimensions , ESTEBAN CHÁVEZ, Instituto Nacional de Investigaciones Nucleares, JULIO HERRERA, Instituto de Ciencias Nucleares, UNAM — A 3-D code has been developed in order to simulate the magnetic field lines in circular cross-section tokamaks. The toroidal magnetic field can be obtained from the individual fields of circular coils arranged around the torus, or alternatively, as a ripple-less field. The poloidal field is provided by a given toroidal current density profile. Proposing initial conditions for a magnetic filed line, it is integrated along the toroidal angle coordinate, and Poincaré maps can be obtained at any desired cross section plane. Following this procedure, the code allows the mapping of magnetic field surfaces for the axisymmetric case. For this work, the density current profile is chosen to be bell-shaped, so that realistic safety factor profiles can be obtained. This code is used in order to study the breaking up of external surfaces when the symmetry is broken by an inner coil with tilted circular loops, with the purpose of modelling the behaviour of ergodic divertors, such as those devised for TEXTOR.

GP8.00108 Fast Particle Losses due to NTMs and Magnetic Field Ripple[1] , E. STRUMBERGER, S. GUENTER, E. SCHWARZ, C. TICHMANN, Max-Planck-Institut fuer Plasmaphysik, ASDEX UPGRADE TEAM — We performed a detailed numerical study for the interaction between fast particles and large scale magnetic perturbations and toroidal field ripple. In particular we focussed our study on the losses of fast ions created by neutral beam injection (NBI) for an ASDEX Upgrade discharge with neoclassical tearing mode (NTM) activity. For these investigations we used as an input an equilibrium carefully reconstructed from experimental data. The ripple is self-consistently included by a 3D, free-boundary equilibrium computation. The magnetic islands caused by (2,1) NTM are introduced by a field perturbation superimposed to the equilibrium magnetic field. Experimental data have been used to reproduce the size and location of those islands numerically. Starting from a realistic seed distribution, the guiding centres of about 100000 fast ions are traced up to a given time limit, or until they hit plasma-facing structures. A detailed analysis of the particle trajectories will provide important information of the underlying loss mechanisms such as: i.) prompt losses of passing particles caused by drift island formation, and ii.) losses of trapped particles due to stochastic diffusion.

[1]IPP-Euratom Association

GP8.00109 Supersonic drift-tearing magnetic islands in tokamak plasmas[1] , RICHARD FITZPATRICK, FRANCOIS WAELBROECK, IFS, U. Texas at Austin — A two-fluid theory of long wavelength, supersonic, drift-tearing magnetic islands in low collisionality, low-β plasmas possessing relatively weak magnetic shear is developed. The model assume s both slab geometry and cold ions, and neglects electron temperature and equilibrium current gradient effects. The problem is solved in two asymptotically matched regions. The "inner region" contains the island. However, the island emits electrostatic drift-acoustic waves which propagate into the surrounding "outer region", where they are absorbed by the plasma. Since the waves carry momentum, the inner region exerts a net force on the outer region, and *vice versa*, giving rise to strong velocity shear in the region immediately surrounding the island. Isolated supersonic islands propagate with a velocity which lies between those of the unperturbed local ion and electron fluids, but is much closer to the latter. The ion polarization current is *stabilizing*, and *increases* with increasing is land width. Finally, the supersonic branch of isolated island solutions *ceases to exist* above a certain critical island width. Supersonic islands whose widths exceed the critical width are hypothesized to bifurcate to the so-called "subsonic" solution branch.

[1]Research funded by U.S. Department of Energy under contract DE-FG05-96ER-54346.

GP8.00110 Nonlinear island dynamics in the presence of sheared toroidal flow[1] , C.C. HEGNA, University of Wisconsin — Recent experimental observations indicate a sensitivity of neoclassical tearing mode threshold physics and saturated island widths to the plasma rotation properties. An analytic theory for nonlinear magnetic island physics in toroidal plasmas is developed that allows for equilibrium toroidal flows. Specifically, equations governing the helical equilibrium state in the vicinity of an isolated magnetic island are developed using an asymptotic theory based on a small island approximation. The island profiles are determined to within three functions of the helical magnetic flux that are subsequently determined by transport properties in the island region. The presence of sheared toroidal flow alter island polarization currents, helical Pfirsh-Schlüter currents produced by pressure and curvature and the Mercier indices needed for the asymptotic matching. The effect of sheared rotation on the external ideal MHD matching data (Δ') will also be addressed.

[1]Research supported by U. S. DoE under grant no. DE-FG02-86ER53218.

GP8.00111 Plasma Rotation Effects on the Externally Driven Magnetic Island Formation[1] , YASUTOMO ISHII, Japan Atomic Energy Agency, ANDREI SMOLYAKOV, University of Saskatchewan — We investigate the effects of the current sheet caused by the Alfven resonance on the magnetic island formation by the externally applied perturbation in rotating plasmas. One of the important problems of the driven magnetic island formation is the onset of the rapid island growth after the flow-suppressed growth phase. This onset is triggered by the plasma rotation reduction around the resonant magnetic surface. In the standard theory on this problem, the plasma rotation is damped by the plasma current formed at the resonant surface. In the low viscosity regime, however, the current sheet is formed not at the resonant surface (neutral line) but around the Alfven resonant surfaces. Hence, the plasma rotation is damped in the wider region than that of the magnetic island width. In this case, the critical value shows weak dependence on the viscosity. We revisit the driven magnetic island formation problem by including the Alfven resonance effects in the wide parameter regime.

[1]This work has been supported by Grant-in-Aids from JSPS (No.17760673)

GP8.00112 Finite Ion Orbit Effects on Magnetic Islands in Toroidal Plasmas , XINZHENG LIU, CHRIS HEGNA, University of Wisconsin — A kinetic theory for the interaction of an ion population with an isolated magnetic island in a high aspect ratio tokamak plasma is presented. We examine islands whose characteristic widths are larger than the ion gyro radius but comparable to the ion banana width. In this regime, the trapped ions do not respond to the island electrostatic potential and helical magnetic geometry due to the banana drifts. When solving the drift kinetic equation for ions, a change in coordinates is used to account for this behavior. A bounce averaging procedure is developed to separate out and solve the lower order distribution function. A two-fluid model is used to determine the electrons response. Quasineutrality leads to a self-consistent calculation for the electrostatic potential. An iteration procedure is introduced to calculate the potential, which is shown to be a combination of functions of the helical flux surfaces and the topologically toroidal flux surfaces. These results are contrasted with the results of small ion orbit case. The contribution to the perturbed current is composed of the helical flux surface-averaged bootstrap current and the perpendicular ion polarization current. Using this current in the Rutherford equation, the island width evolution equation is determined. A pair of self-consistent equations for the island width, w, and its rotation frequency, ω, is to be derived. *Research supported by US DoE under grant No. DE-FG02-86ER53218.

GP8.00113 Critical Toroidal Rotation Profile for Resistive Wall Modes in Tokamaks[1] , K.C. SHAING, University of Wisconsin, M. CHU, General Atomics, S.A. SABBAGH, Columbia University, M. PENG, Oak Ridge National Labpratory — It is known that resistive wall modes in tokamaks can be stabilized by toroidal plasma rotation. The critical toroidal rotation speed is reduced when the enhanced plasma inertia is included in the polarization current density. Here, we develop a model to calculate the critical rotation profile when toroidal plasma rotation is actively controlled. This is accomplished by including the neoclassical dissipation mechanism associated with the perturbed parallel plasma viscosity, and its corresponding inertia enhancement factor. It is illustrated that the important quantity is the toroidal rotation profile and is not necessarily the toroidal plasma rotation speed at a particular radius.

[1]This work was supported by US DOE under Grant No. DE-FG02-02ER54679 and No. DE-FG02-01ER54619 with the University of Wisconsin.

GP8.00114 Toward incorporating the effects of a resistive wall in the linear stability spectrum of ideal MHD with arbitrary equilibrium flows[1] , S.P. SMITH, S.C. JARDIN, Princeton Plasma Physics Laboratory, J.P. FREIDBERG, L. GUAZZOTTO, MIT — The ideal MHD linear stability normal modes and frequencies for a circular cylindrical plasma (having an arbitrary equilibrium flow and a conducting wall at the surface) are calculated using a variational finite element approach. A cubic bspline finite element is used for the radial component of the displacement and the derivative of a cubic bspline is used for the other two components. This both avoids spectral pollution and gives desirable convergence properties. Comparisons of the calculated normal modes and frequencies to analytic results and to other numerical studies are presented. Investigations into the effects of axial and azimuthal flows are also presented. Note that the formulation is such that in the future a resistive wall can be added seamlessly into the code, maintaining the form of a standard eigenvalue problem $\mathbf{A} \cdot \mathbf{x} = \omega \, \mathbf{B} \cdot \mathbf{x}$.

[1]This research was performed under appointment to the Fusion Energy Sciences Fellowship Program administrered by ORISE under a contract between the US DOE and ORAU.

GP8.00115 AEGIS-GK: Gyrokinetic investigation of resistive wall mode stability[1] , L.J. ZHENG, M. KOTSCHENREUTHER, J.W. VAN DAM, Institute for Fusion Studies, Univ. of Texas -Austin — The stability of resistive wall modes (RWM) is an issue of concern for burning plasma confinement, e.g., in ITER. The kinetic resonances, as well as the shear Alfvén resonance, have been shown to be important for RWM stability. However, due to the complexity of kinetic effects, only hybrid models with partial kinetic effects have so far been used to investigate RWM stability. The success in recovering full MHD with our newly derived gyrokinetic theory [Phys. Plasmas **14**, 072505 (2007)] now allows the possibility to study RWMs in a self-consistent kinetic manner. We will present our scheme for a gyrokinetic treatment of RWMs and also analyze various kinetic effects. In particular, we will demonstrate that the parallel electric field, missing in conventional kinetic treatments, cannot be ignored in studying the effects of wave-particle resonances on RWMs. Also, we will show how the kinetic resonances and the shear Alfvén resonance can couple with each other. Preliminary numerical results from the AEGIS-GK code, which incorporates the new gyrokinetic theory, will be also presented.

[1]Research supported by Department of Energy Grant DE-FG02-04ER54742.

GP8.00116 Wall mode stabilization at slow plasma rotation , BO HU, RICCARDO BETTI, University of Rochester, HOLGER REIMERDES, ANDREA GAROFALO, General Atomics, JANARDHAN MANICKAM, Princeton University — Unstable pressure-driven external kink modes, which become slowly growing resistive wall modes (RWMs) in the presence of a resistive wall, can lead to tokamak plasma disruptions at high beta. It has been shown that RWMs are stabilized by fast plasma rotation (about 1-2% of the Alfvén frequency) in experiments. Conventional theories attribute the RWM suppression to the dissipation induced by the resonances between plasma rotation and ion bounce/transit or shear Alfvén frequencies [1]. In those theories, the kinetic effects associated with the plasma diamagnetic frequencies and trapped-particle precession drift frequencies are neglected. It has been observed in recent experiments [2,3] that the RWM suppression also occurs at very slow plasma rotation (about 0.3% of the Alfvén frequency), where the conventional dissipation is too small to fully suppress the RWMs. Here it is shown, that the trapped-particle kinetic contribution associated with the precession motion [4] is large enough to stabilize the RWM in DIII-D at low rotation. Work supported by the US-DoE OFES. [1] A. Bondeson and M. S. Chu, Physics of Plasmas, **3**,3013 (1996). [2] H. Reimerdes *et al.*, Physical Review Letters, **98**,055001 (2007). [3] M. Takechi *et al.*, Physical Review Letters, **98**,055002 (2007). [4] B. Hu and R. Betti, Physical Review Letters, **93**,105002 (2004).

GP8.00117 Stability analysis of resistive wall mode including effects of plasma rotation and error field.[1] , MASARU FURUKAWA, Grad. Sch. Frontier Sci., Univ. Tokyo, LINJIN ZHENG, Inst. Fusion Studies, Univ. Texas at Austin — We have formulated the resistive wall mode stability analysis via an initial-value approach instead of the conventional normal- mode approach in order to resolve the critical rotation for stability and the braking problems. Plasma inertia and rotation are taken into account at a narrow layer around a rational surface. In the plasma region except for the layer, the Newcomb equation (inertia-less MHD equation) is solved. Then the solutions are matched across the narrow layer. In the vacuum region, the Laplace equation for the scalar potential of perturbed magnetic field is solved, and the solutions are connected across a thin resistive wall. In the resistive wall, the diffusion equation for the perturbed magnetic field is solved. Then, we obtain two evolution equations for the amplitude of the mode. The linear growth rates agree well with those obtained by the normal-mode approach. By coupling an evolution equation of the plasma rotation, which includes torque by the mode and error field, we can investigate the quasi-linear evolution.

[1]This work was supported by JIFT exchange program and KAKENHI (19760595).

GP8.00118 Control of magnetohydrodynamic modes in RFPs with a resistive wall above the wall stabilization limit , JOHN FINN, GIAN LUCA DELZANNO, LANL — Studies are shown of control of magnetohydrodynamic (MHD) modes in a cylindrical model for an RFP, in the presence of a resistive wall, below and above the regime for which stabilization is possible with a perfectly conducting wall, i.e. below and above the ideal wall limit. The results show that resistive plasma (tearing-like) modes can be feedback stabilized for current profiles which are unstable below and above the ideal wall limit, for reversed field pinch RFP-like profiles (q(r) decreasing) in a simple model with step function current and pressure profiles. Similar results were found for tokamak-like (q(r) increasing) profiles. However, above the limit for wall stabilization of ideal plasma modes, resonant or non-resonant, the feedback scheme cannot provide stabilization. The control scheme senses both normal and tangential components of the perturbed magnetic field, and the feedback is proportional to a linear combination of the two. More recent results with realistic RFP profiles also show that ideal and resistive (tearing) modes can both be stabilized below their wall stabilization limits. Tearing modes, but not ideal plasma modes, can be stabilized above their wall limits. A physical interpretation of these results is presented. We will also present new results including plasma rotation or complex gain.

GP8.00119 RF Sheath Models[1] , D.A. D'IPPOLITO, J.R. MYRA, Lodestar Research Corporation — RF sheath formation on the antennas and walls in ICRF-heated experiments can reduce the heating efficiency, limit the coupled power, and cause damage to plasma-facing structures. The sheaths are driven by a slow wave component of the rf field due to a mismatch between the magnetic field and the boundary (antenna or wall). Quantitative modeling of the highly nonlinear sheaths may now be feasible for the first time in massively-parallel-processing (MPP) codes developed in the RF SciDAC project. Recently, a new approach to sheath modeling was proposed,[2] in which the sheath physics is incorporated into the RF wave computation by using a modified boundary condition (BC) on the RF fields in both wave propagation and antenna codes. Here, we illustrate the use of the sheath BC for near-field sheaths by a model calculation that includes electromagnetic effects and a simple antenna coupling model. Properties of the model (such as the role of sheath-plasma waves) and implications for antenna codes such as TOPICA[3] will be discussed.

[1]Work supported by US DOE grant DE-FG02-97ER54392.
[2]D.A. D'Ippolito and J.R. Myra, Phys. Plasmas **13**, 102508 (2006).
[3]V. Lancellotti et al., Nucl. Fusion **46**, S476 (2006).

GP8.00120 Electromagnetic high frequency gyrokinetic particle-in-cell simulation of radio frequency waves in magnetically-confined plasmas. , ROMAN KOLESNIKOV, HONG QIN, W.W. LEE, PPPL — Using the gyrocenter-gauge kinetic theory, we developed an electromagnetic version of the high frequency gyrokinetic algorithm [1, 2] for particle-in-cell (PIC) simulation of plasma heating and current drive with RF waves. Gyrokinetic formalism enables separation of gyrocenter and gyrophase motions of a particle in a magnetic field. From this point of view, a particle may be viewed as a combination of a slow gyrocenter and a quickly changing Kruskal ring. The efficiency of the algorithm is due to the fact that the simulation particles are advanced along the slow gyrocenter orbits, while the Kruskal rings capture fast gyrophase physics. The nonlinear dynamics of RF waves is described by the Kruskal rings based on first principles physics. Self-consistent simulation is performed by solving Faraday's and Ampere's laws using Yee's algorithm together with the locally implicit method [3]. We performed a number of simulations of electromagnetic wave propagation in hot inhomogeneous plasmas using new nonlinear delta-f PIC algorithm. Comparisons with a direct Lorentz-force approach are presented. This work is supported by the MSG project (U.S. DoE ASCR Multiscale Mathematics Research and Education Program). [1] R. A. Kolesnikov et al., Phys. Plasmas, **14**, 072506 (2007). [2] H. Qin et al., 17^{th} RF Conference (2007). [3] D.Smithe et al., 17^{th} RF Conference (2007).

GP8.00121 Relativistic effects in electron cyclotron resonance heating and current drive[1] , A.K. RAM, PSFC, MIT, J. DECKER, CEA, Cadarache, France — In the electron cyclotron range of frequencies (ECRF) the X and O modes are used in conventional tokamaks for generating plasma current and for modifying the current profile. The same is envisioned for ITER. In spherical tokamaks (ST) electron Bernstein waves (EBW) are expected to play a similar role. For a proper description of the damping of EC waves, the code R2D2 numerically solves the fully relativistic dispersion relation [1]. It also evaluates the quasilinear diffusion operator for the interaction of EC waves with electrons. This is used in the relativistic three-dimensional Fokker-Planck code LUKE [2] to solve for the electron distribution function. We will present results obtained with R2D2 and LUKE on the relativistic characteristics of EC waves and on the driven plasma current. We will show that the EBW interaction with electrons in present day STs has similar physics to that of O waves interacting with electrons in ITER.
[1] A. K. Ram, J. Decker, and Y. Peysson, *J. Plasma Physics* **71**, 675 (2005).
[2] J. Decker and Y. Peysson, *Euratom-CEA Report EUR-CEA-FC-1736* (2004).

[1]Work supported by DoE Grants DE-FG02-91ER-54109 and DE-FG02-99ER-54521.

GP8.00122 Progress in theoretical and numerical modeling of RF/MHD coupling using NIMROD[1] , THOMAS G. JENKINS, DALTON D. SCHNACK, CHRIS C. HEGNA, JAMES D. CALLEN, CARL R. SOVINEC, University of Wisconsin-Madison, ERIC D. HELD, JEONG-YOUNG JI, Utah State University, SCOTT E. KRUGER, Tech-X Corporation — Preliminary work relevant to the development of a general framework for the self-consistent inclusion of RF effects in fluid codes is presented; specifically, the stabilization of neoclassical and conventional tearing modes by electron cyclotron current drive is considered. For this particular problem, the effects of the RF drive can be formally captured by a quasilinear diffusion operator which enters the fluid equations on the same footing as the collision operator. Furthermore, a Chapman-Enskog-like method can be used to determine the consequent effects of the RF drive on the fluid closures for the parallel heat flow and stress. We summarize our recent research along these lines and discuss issues relevant to its implementation in the NIMROD code.

[1]Work performed as part of the SWIM project, supported by U.S. DoE.

GP8.00123 Sheath boundary in 3-D time-domain edge plasma simulation[1] , D.N. SMITHE, A. HAKIM, Tech-X Corporation, D.A. D'IPPOLITO, J.R. MYRA, Lodestar Research Corporation, E.F. JAEGER, L.A. BERRY, Oak Ridge National Laboratory, SCIDAC CENTER FOR SIMULATION OF WAVE-PLASMA INTERACTIONS TEAM — A general purpose time-domain plasma simulation algorithm has been constructed and implemented in the VORPAL software framework.[1] It is able to represent the complex physical boundaries of the ICRF antenna structure, and complex magnetic topology of the edge region. This time-domain algorithm is now being supplemented with a sub-grid boundary sheath model based upon the work of D'Ippolito et al.[2] We verify the model against known behavior from frequency-domain sheath calculations in 1-dimension. We also test the model in 3-D simulation including RF launcher geometry, and compare results with related models being implemented in 1, 2, and 3-D full wave solvers. This new model will provide realistic estimates of power loss due to short range sheaths. We will also present possible strategies for treating mid and long range sheaths within the model.

[1] D. N. Smithe, Physics of Plasmas, Vol. 14 056104 (2007).
[2] D. A. D'Ippolito and J. R. Myra, Phys. Plasmas 13, 102508 (2006).

[1]This work supported by PPPL subcontract S-006288-F.

GP8.00124 Simulation of High Power ICRF Wave Heating in the ITER Burning Plasma[1] , E.F. JAEGER, L.A. BERRY, R.F. BARRETT, E.F. D'AZEVEDO, Oak Ridge National Laboratory, SCIDAC CENTER FOR SIMULATION OF WAVE-PLASMA INTERACTIONS TEAM — ITER relies on Ion-cyclotron Radio Frequency (ICRF) power to heat the plasma to fusion temperatures. To heat effectively, the waves must couple efficiently to the core plasma. Recent simulations using AORSA [1] on the 120 TF Cray XT-4 (Jaguar) at ORNL show that the waves propagate radially inward and are rapidly absorbed with little heating of the plasma edge. AORSA has achieved 87.5 trillion calculations per second (87.5 teraflops) on Jaguar, which is 73 percent of the system's theoretical peak. Three dimensional visualizations show "hot spots" near the antenna surface where the wave amplitude is high. AORSA simulations are also being used to study how to best use ICRF to drive plasma currents for optimizing ITER performance and pulse length. Results for Scenario 4 show a maximum current of 0.54 MA for 20 MW of power at 57 MHz.

[1] E.F. Jaeger, L.A. Berry, E. D'Azevedo, *et al.*, Phys. Plasmas. **8**, 1573 (2001).

[1]This research used resources of the National Center for Computational Sciences at Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

GP8.00125 Full wave simulations of lower hybrid waves in toroidal geometry with non-Maxwellian electrons , JOHN WRIGHT, MIT, ERNEST VALEO, CYNTHIA PHILLIPS, PPPL, PAUL BONOLI, MIT, MARCO BRAMBILLA, IPP-Garching, RF-SCIDAC TEAM — Analysis of LH wave propagation in the past has been done using ray tracing and the WKB approximation. Advances in algorithms and the availability of massively parallel computer architectures has permitted the solving of the Maxwell-Vlasov system for wave propagation directly. These simulations have shown that the bridging of the spectral gap (the difference between injected phase velocities and the velocity at which damping on electrons occurs) can be explained by the diffraction effects captured by the full wave algorithm - an effect missing in WKB based approaches. However, these full wave calculations were done with a Maxwellian electron distribution and it is well know that a quasilinear plateau between the point of most efficient damping on electrons at about 2-3 v_{te} and where collisional and quasilinear diffusion balance. Ray tracing codes have long iterated to a self-consistent steady state with Fokker-Planck codes. To address this discrepancy and better model experiment, we have implemented a non-Maxwellian dielectric in our full wave solver. We will show how these effects improve coupling and penetration into the plasma of the waves and show comparisons with ray tracing and experiment.

GP8.00126 Influence of the poloidal phase difference of antenna current on eigenmodes and power absorption in the ion cyclotron range of frequencies , SUWON CHO, Kyonggi University, JONG-GU KWAK, Korea Atomic Energy Research Institute — The load resilient antenna utilizing the conjugate T matching method is known to be effective in the rf power coupling for ELMy plasmas. Contrary to the conventional antenna, the load resilient antenna can have the phase difference of the current between the two straps above and below the equatorial plane, which may affect the heating efficiency. In this work, effects of the phase difference are examined using the full wave simulation code TORIC. It is found that the poloidal phase difference can cause eigenmodes to appear at different toroidal mode numbers and it influences power absorption especially large when distinct eigenmode modes are excited. They can exist over the entire range of the toroidal mode number when the density is relatively low and can exist at either very low values or high values of the toroidal mode number otherwise. As the density increases, distinct eigenmodes at particular toroidal mode numbers disappear smoothing the power absorption spectrum except for a few lowest toroidal mode numbers and interference due to the poloidal phase difference generally leads to weak power absorption over the broad range of the toroidal mode number.

GP8.00127 Design of the ITER Electron Cyclotron Heating and Current Drive Waveguide Transmission Line , T.S. BIGELOW, D.A. RASMUSSEN, Oak Ridge National Laboratory, M.A. SHAPIRO, J.R. SIRIGIRI, R.J. TEMKIN , MIT Plasma Science and Fusion Center, H. GRUNLOH, General Atomics, J. KOLINER, Department of Physics, Arizona State University — The ITER ECH transmission line system is designed to deliver the power, from twenty-four 1 MW 170 GHz gyrotrons and three 1 MW 127.5 GHz gyrotrons, to the equatorial and upper launchers. The performance requirements, initial design of components and layout between the gyrotrons and the launchers is underway. Similar 63.5 mm ID corrugated waveguide systems have been built and installed on several fusion experiments; however, none have operated at the high frequency and long-pulse required for ITER. Prototype components are being tested at low power to estimate ohmic and mode conversion losses. In order to develop and qualify the ITER components prior to procurement of the full set of 24 transmission lines, a 170 GHz high power test of a complete prototype transmission line is planned. Testing of the transmission line at 1-2 MW can be performed with a modest power (~0.5 MW) tube with a low loss (10-20%) resonant ring configuration. A 140 GHz long pulse, 400 kW gyrotron will be used in the initial tests and a 170 GHz gyrotron will be used when it becomes available. Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

GP8.00128 Modulated LHCD with Feedbak control to Active Suppress MHD m=2 on HT-7[1]

, J.S. MAO, J.R. LUO, Y.W. SUN, B.J. DING, Institute of Plasma Physics, Chinese Academy of Sciences — A crucial issue for the extension of advanced tokamak scenarios to long pulse operation is the avoidance of Magneto-Hydrodynamics (MHD) activity. Active Modulation of Lower Hybrid Current Drive (LHCD) was used successfully to suppress MHD activity on HT-7, a superconducting tokamak. A feedback system was used which activated modulation only when MHD activity reach a predetermined level so as to optimize the current drive through out the discharge. The LHCD modulation was varied in power and frequency, with the frequency always being less than the resistive skin time (100ms). Optimal MHD suppression was achieved when modulating LHW power $>$ 200kW, and frequency of 50Hz. Details of the MHD suppression will be discussed in this poster. Active Modulation of LHCD was used successfully to suppress MHD activity. This was achieved in discharges with MHD m=2 tearing modes during the discharge conditions Ip=110KA, Bt=1.75T, Ne$\sim$1.1x1013cm^{-3}. The amplitude, interval and the period of LHCD modulation pulse can be adjusted very conveniently. The modulation LHCD can be delivered very fast at the any time during the discharge. The modulation LHCD period was always much shorter than the plasma resistive time. So the profile of plasma current is changed much fast than the plasma resistive time. The different forms of LHCD modulating can be proved.

[1]This work was Support by National Natural Science Fund of China. Contract No. 10675126 and 10275068.

GP8.00129 SIMULATION: MHD —

GP8.00130 SIESTA: an Scalable Island Equilibrium Solver for Toroidal Applications[1]

, RAUL SANCHEZ, STEVEN HIRSHMAN, VICKIE LYNCH, Oak Ridge National Laboratory — The construction and development of a new ideal MHD 3D-equilibrium solver, capable of dealing with magnetic islands and stochastic regions in a fast, accurate and scalable manner will be described. The SIESTA code will complement other existent 3D MHD island solvers and is particularly suited for applications that require not only accuracy but speed of evaluation as well, such as experimental 3D equilibrium reconstruction or stellarator design. SIESTA will also be useful to calculate MHD equilibria at very high spatial resolutions, such as those that might be required for the investigation of NTMs at ITER-relevant temperature and resistivity conditions. SIESTA is based on a preconditioned, iterative algorithm that takes advantage of a pre-existent VMEC solution to provide both a background coordinate system that guarantees a compact representation as well as a good initial guess for the iterative procedure. Details of the algorithm implementation, its performance on some simple test problems and initial steps towards its porting to a massively parallel environment will be discussed.

[1]Research supported by USDOE under contract No. DE-AC05-00OR22725.

GP8.00131 Results from the PSI-Center Interfacing Group

, B.A. NELSON, C.C. KIM, A.I.D. MACNAB, R.D. MILROY, T.R. JARBOE, University of Washington, J. KESNER, M.I.T., D.T. GARNIER, Columbia University, C.R. SOVINEC, University of Wisconsin-Madison, P.M. BELLAN, Caltech, M.R. BROWN, Swarthmore College — The Interfacing Group of the Plasma Science and Innovation Center (PSI–Center — http://www.psicenter.org) facilitates simulations of collaborating Innovative Confinement Concept (ICC) experiments. Present collaborating experiments include the Bellan Plasma Group (Caltech), FRX–L (Los Alamos National Laboratory), HIT–SI (Univ of Wash — UW), LDX (M.I.T.), MBX (Univ of Texas–Austin), MST, Pegasus (Univ of Wisc–Madison), PHD (UW), SSPX (Lawrence Livermore National Laboratory), SSX (Swarthmore College), TCS (UW), and ZaP (UW). NIMROD code meshes have been created and/or modified for the Caltech, SSX, and LDX experiments. Simulations of the Caltech and SSX experiments study formation and buildup of electrode-driven helicity injection. LDX simulations study stability of marginally-stable equilibria as additional heating increases pressure gradients. NIMROD output files are interfaced to the powerful 3-D viewer, VisIt (http://www.llnl.gov/visit), which will be demonstrated. Results from these simulations, as well as an overview of the Interfacing Group status will be presented.

GP8.00132 MHD Simulations with Self Consistent Boundary Conditions

, G.J. MARKLIN, T.R. JARBOE, Plasma Science and Innovation Center, University of Washington, Seattle, Washington 98195 — Modern ICC experiments, such as those using inductive helicity injection and rotating field current drive, use insulation to allow flux from multiple circuits to enter and form complex patterns of rotating E&M fields over the surface. The HIT-SI geometry is used to develop a new method of handling such boundary conditions for 3D simulations. The insulating layer between the plasma and the conducting wall allows magnetic flux to move along the surface at the speed of light, assumed to be infinite, until it finds equilibrium with the plasma and circuit conditions it encounters on each time step. This 2D surface equilibrium determines the locally self consistent magnetic boundary condition. Plasma inflow is used to model gas injectors and the momentum boundary condition couples to the surface magnetic field leading to a nonlinear Poisson equation. This poster will derive these surface equilibrium equations and show how they are solved on a tetrahedral mesh. Simulations of a spheromak tilting mode in a cylinder, a toroidal RFP, and HIT-SI will show the difference between the insulated conductor and the conventional bare conductor boundary condition. The HIT-SI results will be compared with experimental data to determine whether the physics of the resistive MHD model is adequate to describe observed reconnection rates.

GP8.00133 The Effect of a Weak Toroidal Field on the n=2 Rotational Instability in an FRC

, R.D. MILROY, L.C. STEINHAUER, A.I.D. MACNAB, C.C. KIM, University of Washington, C.R. SOVINEC, University of Wisconsin, Madison — The n=2 rotational instability has almost always been observed in dynamically formed FRCs. This instability is driven by centrifugal forces in the rotating plasma, but can be stabilized with multipole fields. Translated FRCs often do not exhibit this instability and a recent analysis [H.Y. Guo, et al., Phys. Rev. Lett. 95, 17001 (2005)] implies that a small toroidal field could stabilize it. We are investigating this effect numerically with the NIMROD code, and analytically using the energy principal. When modest toroidal magnetic field is added to an FRC with its high elongation and small aspect ratio, a spherical torus like configuration can be formed with a safety factor q exceeding 1 over the entire configuration. We have found that the addition of a relatively weak toroidal magnetic field to an FRC can stabilize the n=2 rotational instability, but for calculations that do not include the Hall term, a more complex n=2 mode remains unstable. Inclusion of the Hall term can dramatically reduce the growth rate, or stabilize this mode too.

GP8.00134 Nonlinear MHD simulation of DC helicity injection in spherical tokamaks

, R.A. BAYLISS, C.R. SOVINEC, Univ. of Wisconsin - Madison — 3-D nonlinear MHD computations using the NIMROD code have been performed to study DC helicity injection in the HIT-II and Pegasus spherical tokamaks. Current drive via DC helicity injection has been successfully employed with either a poloidal-gap voltage known as coaxial helicity injection (CHI) [used in HIT-II and NSTX] or a biased miniature plasma gun [used in CDX and Pegasus]. Numerical studies of CHI in a simplified geometry with $\beta = 0$ reproduce the “bubble-burst” formation and the subsequent excitation and saturation (characterized in HIT-II by amplification of poloidal flux) of a line-tied internal kink-mode. The computed strength of saturated fluctuations and poloidal flux are in quantitative agreement with data obtained in the HIT-II experiment. Results from $\beta \neq 0$ simulations with an experimentally accurate geometry will also be presented. Cases driven by a numerical representation of miniature plasma gun self-consistently evolve pressure and anisotropic thermal transport and simulate the formation, merger, and relaxation of the current filaments to a tokamak-like plasma. The results are compared to experimental data from the Pegasus ST. In both injection scenarios the simulations permit a detailed description of the 3-D equilibria exhibited by the helicity-injected driven plasma and reproduce the observations made in the Pegasus ST and HIT-II of amplified poloidal flux and generation of toroidal current.

GP8.00135 Impact of velocity space distribution on hybrid kinetic MHD simulation of the $(1, 1)$ internal kink mode , CHARLSON C. KIM, University of Washington - PSI Center, NIMROD TEAM — Simulation studies of the impact of the velocity space distribution on the stabilization of $(1, 1)$ internal kink mode and excitation of the fishbone mode were performed with a hybrid kinetic MHD model. The simulations were performed by extending the physics capabilities of **NIMROD**(Non-Ideal MHD with Rotation - Open Discussion)–a three dimensional extended magnetohydrodynamic (MHD) code– to include kinetic effects of an energetic minority ion species. These kinetic effects are included by computing a pressure moment tensor using δf particle-in-cell (PIC) method. The marker particles are advanced in the self consistent NIMROD fields. We outline the implementation and present simulation results of energetic minority ion stabilization of the $(1, 1)$ internal kink mode and excitation of the fishbone mode. A benchmark of the linear growth rate and real frequency are shown to agree well with M3D. We examine the impact of the details of the velocity space distribution such as extending the velocity space cut off and the impact of passing versus trapped particles and show that they strongly impact the stabilization and excitation of the $(1, 1)$ mode.

GP8.00136 Nonlinear simulations of the m=0 instability development in z-pinch equilibria with axial sheared flows[1] , IOANA PARASCHIV, BRUNO S. BAUER, IRVIN R. LINDEMUTH, VOLODYMYR MAKHIN, University of Nevada Reno — A detailed study of the linear and nonlinear development of the m=0 instability in the presence of sheared axial flows has been performed using a two-dimensional magnetohydrodynamic numerical code, MHRDR, to solve single-fluid ideal MHD equations. In order to accurately study the sheared flow effects on the z-pinch stability, the code was modified to include periodic boundary conditions and a monotonic van Leer advection algorithm. Linear growth rates obtained with MHRDR were in good agreement with the linear theory (<10% difference). Nonlinear mode coupling and saturation of the sausage instability have been studied for z-pinch equilibria with and without sheared flows. It was found that sheared flows changed the m=0 development by reducing the linear growth rates, decreasing the saturation amplitude, and modifying the instability spectrum. High spatial frequency modes were stabilized to small amplitudes, and only the long wavelengths continued to grow. Full stabilization was predicted for supersonic plasma flows.

[1]Work supported by DOE-OFES grants DE-FG02-04ER54752 and DE-FG02-06ER54892

GP8.00137 Time-dependent closures for plasma fluid equations[1] , ERIC HELD[2], JEONG-YOUNG JI[3], MICHAEL ADDAE-KAGYAH, Utah State University, NIMROD TEAM, CEMM SCIDAC COLLABORATION, PSI-CENTER COLLABORATION — Two approaches to calculating time-dependent parallel closures for plasma fluid equations are presented. Both solve a lowest-order drift kinetic equation that includes time dependence, free streaming, and an exact treatment of the linearized Coulomb collision operator. The first approach extends the theory of Chang and Callen [4] by including additional moments in the treatment of the collision operator as well as initial value effects for the distribution function. Time-dependent equations for the closures are derived via inverse Laplace/Fourier transforms of single pole approximations to the pseudotransport equations. The second approach entails a continuum solution to the drift kinetic equation using 2-D finite elements for the velocity space variables. As enhancements to the first approach, this method allows for arbitrary geometry as well as the full Coulomb collision operator.

[1]Research supported by the U.S DOE under grants nos. DE-FG02-04ER54746, DE-FC02-04ER54798 and DE-FC02-05ER54812.
[2]presently on sabbatical at U. of Wisconsin-Madison
[3]presently on sabbatical at U. of Wisconsin-Madison
[4] Z. Chang and J. D. Callen, *Phys. Fluids B* **4** (5), 1167 (1992).

GP8.00138 Comparing Reduced Fluid Models to the Two-Fluid Plasma System , BHUVANA SRINIVASAN, URI SHUMLAK, Aerospace and Energetics Research Program, University of Washington — The two-fluid plasma model is studied and compared to reduced fluid models such as Hall-MHD. Three asymptotic approximations are independently applied to the full two-fluid plasma model to obtain the reduced models which include charge neutrality, infinite speed of light and negligible electron inertia. Hall-MHD is pursued because it captures additional physics as compared to ideal MHD. The additional physics takes into account two-fluid effects by using the Hall and the diamagnetic drift terms believed to be important in Hall accelerators, Z-pinches, Field Reversed Configurations, and other such applications. Two-fluid effects become significant when the characteristic spatial scales are small compared to the ion skin depth and the characteristic time scales are short compared to the inverse ion cyclotron frequency. The motivation here is to compare Hall-MHD to the two-fluid model to study the physics that is lost or captured by applying the approximations in addition to comparing the simplicity of implementation of the models. Simulations of electromagnetic plasma shock, and current sheets with in-plane magnetic fields (i.e. collisionless reconnection) and out-of-plane magnetic fields are performed and the results are compared between the models.

GP8.00139 Two-fluid simulations of sawteeth in a periodic boundary driven screw-pinch.[1] , V.S. LUKIN, S.C. JARDIN, Princeton Plasma Physics Laboratory — We numerically study non-linear evolution of m=1 internal kink mode in 2D helical geometry. Initial value simulations have been conducted with the macroscopic modeling code SEL. A number of plasma fluid models, from reduced MHD to full two-fluid extended MHD, have been applied to the problem. Both resistive and two-fluid evolution of an ideally unstable initial condition through full Kadomtsev reconnection is studied. In the semi-collisional regime, onset of fast reconnection is shown to be correlated with the width of resistive current sheets falling below characteristic inertial scales available to the system. In simulations with assumed peaked radial profile of conductivity and Ohmic current drive, formation of a helical paramagnetic quasi- equilibrium with enhanced stability properties is observed following the initial reconnection event. Plasma is then shown to produce periodic sawtoothing behavior which is independent of the initial conditions. Observed sawteeth are characterized by relatively slow semi-resistive kinking followed by apparent onset of the quasi-interchange mode on an ideal MHD time-scale. Incomplete reconnection of the plasma core, maintaining the safety factor q in the central plasma region below unity throughout a sawtooth cycle, is demonstrated.

[1]This work was supported under NSF Graduate Research Fellowship and by the DOE contract DE-AC02-76-CHO3073.

GP8.00140 Toroidal Axisymmetric Extended-MHD Steady-States with Flow , N.M. FERRARO, S.C. JARDIN, Princeton Plasma Physics Laboratory, A.C. BAUER, Rensselaer Polytechnic Institute — Axisymmetric steady-states of the full extended-MHD (X-MHD) equations, including two-fluid effects, flow, and gyroviscosity, are obtained by evolving the X-MHD equations from an initial ideal-MHD equilibrium. Steady-states for both large aspect-ratio limited plasmas and NSTX-like diverted plasmas are presented. Self-consistent Pfirch-Schlüter flows are observed, and spontaneous spin-up is observed to develop even when a simple resistive single-fluid model is used, in agreement with previous theoretical and numerical results. In the steady-state, resistive and thermal losses are offset by inductive current drive. These accurate and self-consistent steady-states may be used as the initial equilibrium for non-axisymmetric X-MHD linear stability calculations, for example. The axisymmetric steady-states are obtained using M3D-C^1, a parallel, implicit, nonlinear, high-order finite element code. Cylindrical coordinates are used instead of flux coordinates, eliminating difficulties arising from the coordinate singularity at the magnetic x-point in diverted plasmas. The vacuum region is modeled as a high-resistivity plasma, allowing the same physical equations to be applied throughout the simulation domain. An unstructured, adaptive triangular mesh is used to maximize computational efficiency without degrading spatial resolution. This work was supported by US DOE contract DE-AC02-76CH03073.

GP8.00141 A New Code for Resistive Wall Mode Modeling with 3D Conducting Structures

, YUEQIANG LIU, Chalmers University of Technology, Sweden, R. ALBANESE, Universita di Napoli, Italy, A. PORTONE, EFDA CSU, EU, G. RUBINACCI, Universita di Napoli, Italy, F. VILLONE, Universita di Cassino, Italy — The resistive wall mode (RWM) is a macroscopic MHD instability that limits the fusion power production of advanced tokamaks. Realistic modeling of this mode often requires detailed 3D description of the conducting structures such as the surrounding resistive wall. We have developed a new code CarMa [1] by coupling the MHD stability code MARS-F [2] with the 3D finite element based eddy current code CARIDDI [3]. The coupling scheme is shown correct both analytically and numerically. Feedback stabilization of RWM is investigated for ITER advanced scenarios.

[1] R. Albanese, et al., COMPUMAG 2007 conference, Aachen (Germany), June 2007
[2] Y.Q. Liu, et al., Phys. Plasmas 7, 3681 (2000)
[3] R. Albanese, G. Rubinacci, Adv. Im. El. Phys.,102, 1-86, Acad. Press 1998

GP8.00142 Simulations of NTM Stabilization using Current Drive Offset Relative to the ISLAND Center[1]

, JENNIFER WOODBY, EUGENIO SCHUSTER, ARNOLD KRITZ, GLENN BATEMAN, ALEXEI PANKIN, Lehigh University — High plasma pressure can cause simply nested magnetic flux surfaces to tear and reconnect, leading to the formation of magnetic islands. The neoclassical tearing mode (NTM) instability drives magnetic islands to grow to saturated widths, at which the islands can persist stably. The presence of magnetic islands leads to a local flattening of the pressure profile and locally hollow current profile within the island. The flattening of the pressure profile is undesirable in that it can result in degradation of plasma confinement. One common method of stabilizing NTMs and shrinking the magnetic islands is to replace the diminished currents within the islands using direct current injection via electron cyclotron current drive. Maximum stabilization is achieved when current is driven at the island center, the location of which is not accurately known in experiments. In this study, the current drive is expressed mathematically as a Gaussian current drive density in Hamada coordinates. The effect of current drive offset relative to the island center is investigated in preparation for feedback control.

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), and the NSF CAREER award program (ECCS-0645086).

GP8.00143 Numerical Studies of Linear Two Fluid Tearing Modes in Slab and Cylindrical Geometries[1]

, J.R. KING, C.R. SOVINEC, V.V. MIRNOV, University of Wisconsin — The NIMROD code is applied to two-fluid tearing computations in slab and cylindrical geometry. Linear computations in slab geometry with large guide field and force-free equilibria scan plasma beta and the tearing stability parameter for benchmarking with analytical theory. A revised meshing algorithm improves numerical resolution, and convergence studies for all parameter regimes are presented. Growth rates approach the MHD values at beta values much less than 1%. Nonlinear results for these force-free cases show broadening of a Hall dynamo effect to the island width scale upon saturation. The effect of adding guide field to the non-force-free GEM problem is also investigated; fast two-fluid reconnection becomes suppressed. Finally, cylindrical force-free linear calculations with parameters relevant to the Madison Symmetric Torus Reversed Field Pinch are compared to existing analytics. The broadening of the flow-velocity profile is understood qualitatively from the analytical foundation. Requirements for nonlinear 3D two-fluid cylindrical computations are also considered.

[1]Supported by US DOE.

GP8.00144 Simulations of Decaying Kinetic Alfvén Wave Turbulence: Intermittent and Coherent Structures

, KURT SMITH, PAUL TERRY, UW-Madison — We simulate decaying kinetic Alfvén wave turbulence in a strong guide field, appropriate for modeling interstellar turbulence at scales $\leq 10\rho_s$. Ion flow decouples from the system at these scales, while electron density fluctuations equipartition with the magnetic field. From an initial Gaussian distribution, the system decays to a non-Gaussian PDF characterized by a large current kurtosis and positive-edge, negative-core Gaussian curvature filaments. Current filaments and their associated magnetic and density structures are long-lived, unmixed by the surrounding turbulence. The intensity of density structures does not scale with the intensity of current filaments, since the system permits a density structure to exist with a corresponding filament of either sign. Structures merge only if they correspond to like-signed current filaments. We investigate the scaling of structure radial extent with magnitude, the physics of structure mergers, and the averaged radial profile of density structures outside the core region, proposed to track the r^{-1} profile of the magnetic field.—Work supported by NSF.

GP8.00145 Kinetic excitation of Alfvénic instabilities near the second ballooning stability boundary in a high-β toroidal plasma[1]

, ANDREAS BIERWAGE, LIU CHEN, Department of Physics and Astronomy, University of California, Irvine, CA 92697, USA — The kinetic excitation and/or damping of plasma waves in a high-β tokamak plasma is studied using linear gyrokinetic simulations. A new code was developed to accurately simulate excitations in a broad range of frequencies and wavelengths. It describes the evolution of the electromagnetic fields $\delta\mathbf{B}_\perp$, $\delta B_\parallel$ and $\delta E_\parallel$ subject to effects of kinetic compression of thermal and energetic ions, finite Larmor radii and finite drift orbit widths. The s-α equilibrium model and ballooning representation are employed. For example, the code is capable of investigating kinetic ballooning modes, Alfvénic ion temperature gradient modes, β- and toroidicity-induced Alfvén eigenmodes, and energetic particle modes. Our current focus is on the parameter regime near the second ballooning stability boundary, where the properties of Alfvénic instabilities including kinetic thermal ion compression will be examined. Corresponding results will be reported as they become available.

[1]This research is supported by United States DOE and NSF Grants.

GP8.00146 Large Eddy - Lattice Boltzmann (LES-LB) Simulations of Fluid and MHD Turbulence[1]

, BRIAN KEATING, William & Mary, MIN SOE, Rogers State University, GEORGE VAHALA, William & Mary, LINDA VAHALA, Old Dominion University, JEFFREY YEPEZ, ARFL, Hanscom Field, JONATHAN CARTER, NERSC, LBNL — For high Reynolds number turbulence, the resource requirements for a full space-time DNS simulation scales as Re^3 – which is far beyond any foreseeable computational resources. For problems that require instantaneous fields, one is forced into an LES in which one filters out the unresolvable small scales in the simulation but must then deal with the effects of the subgrid scales on the resolvable scales. In the Lattice Boltzmann (LB) mesoscopic approach one sidesteps the stiff nonlinear convective derivatives in the nonlinear continuum equations by simple linear advection in kinetic space together with local collisional relaxation at each spatial node. The relaxation distribution functions have simple algebraic continuum nonlinearities. In LES, the Smagorinsky eddy viscosity is related to the mean rate of strain tensor. However this tensor can be computed from purely locally moments in LB. In a Smagorinsky LES-MHD, the subgrid magnetic Reynold stress can be determined from local kinetic moments.

[1]work supported by DoE and AFOS

GP8.00147 Low Frequency Plasma Lagrangian

, H. VERNON WONG, Institute for Fusion Studies, University of Texas at Austin — A formulattion of the plasma Lagrangian for low frequency electromagnetic perturbations is discussed, The analysis is based on a small Larmor radius expansion of the Vlasov equation in which the perpendicular magnetohydrodynamic (MHD) response is separated from the intrinsic parallel particle response. The Euler-Lagrange equations reproduce the linearized MHD and drift-kinetic equations. Hybrid "fluid-kinetic" equations are readily derived, with inclusion of kinetic and finite Larmor radius effects. Gauge invariance is preserved, and any representation of the perturbed fields can be accommodated.

GP8.00148 Magnetohydrodynamics inside a rotating sphere.

, DAVID MONTGOMERY[1], Dartmouth College, Hanover, NH 03755, PABLO MININNI[2], NCAR, Boulder, Colorado 80307, LEAF TURNER[3], Cornell University, Ithaca, NY 14853 — The equations of incompressible MHD are solved inside a uniformly rotating rigid spherical shell. The method of solution is a Galerkin expansion for the vector fields involved. The normal components of these fields vanish at the spherical boundary. The expansion basis functions are the spherical Chandrasekhar-Kendall eigenfunctions of the curl. A prescribed mechanical forcing excites a wide variety of dynamo behavior, all (so far) at unit magnetic Prandtl number. Key control parameters seem to be mechanical and magnetic Reynolds numbers, the Rossby and Ekman numbers (which we vary by varying the rotation rate of the sphere), and the amount of mechanical helicity injected. Magnetic energy levels and magnetic dipole behavior fluctuate strongly in a few eddy turnover times, but seem to stabilize as the rotation rate is increased, until the limit of the code resolution is reached. The detailed geometry of the mechanical forcing appears to be important. [P.D.Mininni et al, Phys. Fluids 18, 116602 (2006) and New Journ. of Physics (to appear, 2007).]

[1]supported in part by the NSF
[2]supported in part by the NSF
[3]supported in part by the NSF

GP8.00149 Plasma Wave Echoes in a Weakly Collisional Plasma[1]

, C. BLACK, K. GERMASCHEWSKI, C.S. NG, A. BHATTACHARJEE, Center for the Integrated Computation and Analysis of Reconnection and Turbulence (CICART), University of New Hampshire, Durham, NH 03824 — It has been shown recently that weak collisions, which are a singular perturbation on the collisionless Vlasov equation, have a profound effect on the underlying spectrum for linear plasma waves by eliminating the Case-Van Kampen continuous spectrum and replacing it with a complete class of discrete eigenmodes [C.S. Ng, A. Bhattacharjee, F. Skiff, Phys. Rev. Lett. **83**, 1974 (1999); **92**, 065002 (2004).]. This discovery has important consequences for the validity of the classical theory of C. H. Su and C. Oberman [Phys. Rev. Lett. **20**, 427 (1968)] on the collisional decay of plasma wave echoes. We have developed a parallel one-dimensional Vlasov-Poisson system solver including the Lenard-Bernstein collision operator, and benchmarked this code with our earlier numerical results on the discrete spectrum. We have also completed simulations of plasma wave echoes in the collisionless system. We will report our results on the effect of collisions on the echoes, testing the theory of Su and Oberman, and present some novel features in echo dynamics caused by the discrete spectrum of collisional eigenmodes.

[1]This research is supported by NSF and DOE.

GP8.00150 Driven, autoresonant three-oscillator interactions[1]

, ODED YAAKOBI, LAZAR FRIEDLAND, Hebrew University of Jerusalem, ZOHAR HENIS, Soreq Research Center — An efficient control scheme of resonant three-oscillator interactions (R3OI) using an external chirped frequency drive is suggested. The approach is based on formation of a double phase- locked (autoresonant) state in the system, as the driving oscillation passes the linear resonance with one of the interacting oscillators. When doubly phase-locked, the amplitudes of the oscillators increase with time in proportion to the driving frequency deviation from the linear resonance. The stability of this phase-locked state, the effects of dissipation and of the initial three-oscillator frequency mismatch on the autoresonance are analyzed. The associated autoresonance threshold phenomenon on the driving amplitude is also discussed. In contrast to other nonlinear systems, driven, autoresonant three-oscillator excitations are independent of the sign of the driving frequency chirp rate.

[1]Supported by the US-Israel Binational Science Foundation, grant No. 2004033

GP8.00151 MH4D Benchmarking and Atomic Physics Implementation

, ERIC MEIER, University of Washington, PSI-CENTER COLLABORATION — Two key benchmarks of MH4D have been made: 1) Screw pinch kink and spheromak tilt modes have been simulated in MH4D with non-linear ideal MHD. Linear growth rates are compared to results from linear stability computations. 2) MH4D has been used to simulate the ZaP Flow Z-Pinch experiment, and benchmarked against results from a well-developed 2-D MHD code, MACH2. Periodic boundary conditions are used in MH4D to allow quasi-2D simulation. Resistivity and ohmic heating are included in these simulations. Beyond these benchmarks, the 3-D capability of MH4D has been explored by simulating gas injection in ZaP. Also, the accuracy and utility of the implicit and semi-implicit features of MH4D have been assessed. First order atomic physics have been implemented in MH4D. A cold static neutral fluid is tracked, and the applicable temperature-dependent ionization, recombination, and charge exchange terms are included in each of the MHD equations and in the neutral fluid density equation. A significant background density of neutral fluid is shown to cause the expected slowing of spheromak tilt mode growth. The effect of ionization (delayed plasma generation) on ZaP plasma dynamics is explored.

GP8.00152 OPTIMAL HELICON SOURCE PERFORMANCE —

GP8.00153 Cross-correlation diagnostics of electrostatic fluctuations in a helicon source

, MICHAEL KRAEMER, Ruhr University Bochum — The absorption of helicon waves was observed to be intimately connected with the excitation of short-scale electrostatic fluctuations [1]. Cross-correlation techniques using microwave back-scattering at the upper-hybrid resonance as well as electrostatic probes enable measurements of their frequency and wavenumber spectra. The low-frequency band can be attributed to ion-sound fluctuations, while the high-frequency fluctuations obey the dispersion relation of Trivelpiece-Gould waves. The fluctuations satisfy the matching conditions for the parametric decay instability of the helicon wave. Operating the helicon discharge in a pulsed mode, the growth rates and the thresholds of the fluctuations can be deduced from their temporal growth in a wide parameter range. Good agreement with a theory that accounts for the non-zero axial wavenumber of the helicon pump was achieved. The close relationship between the rf absorption and the excitation of the fluctuations is studied in more detail by performing time- and space-resolved measurements of the helicon field and the electrostatic fluctuations. In particular, the role of the radial plasma inhomogeneity on the parametric excitation of the fluctuations is examined.-Supported by the Deutsche Forschungsgemeinschaft (SFB 591, Project A7).- [1] B. Lorenz, M. Krämer, V.L. Selenin, Yu.M. Aliev, Plasma Sources Sci. Technol. **14**, 623 (2005).

GP8.00154 Slow wave measurement using the WVU 300 GHz collective scattering diagnostic

, ROBERT HARDIN, West Virginia University, EARL SCIME, ALEX HANSEN — Recent experiments in helicon plasma sources by Krämer *et al.* [2006] and Kwak *et al.* [2006] have employed mm-wave technology to investigate electron densities in a pulsed source and density fluctuations due to ion-acoustic waves, respectively. Measurement of the temporal and spatially resolved electron densities by Kramer was accomplished with a mm-wave interferometer. The ion-acoustic waves measured by Kwak employed a collective scattering system with a heterodyne detection scheme. The WVU 300 GHz quasi-optical collective scattering diagnostic, uses a homodyne detection method similar to the interferometer, designed to measure the "slow" wave. Experimental parameters observed to heat ions in the plasma edge in conjunction with theoretically calculated wave numbers associated with the slow wave, as seen in Kline *et al.* [2002], were examined for evidence of the slow wave using the mm-scattering diagnostic. Here we present initial wave number spectrum measurements of the slow wave in a helicon plasma source. M. Krämer, B. Clarenbach, and W. Kaiser, Plasma Sources Sci. Technol. **15**, 332 (2006). J.G. Kwak, S.J. Wang, S.K. Kim, and S. Cho, Phys. Plasmas **13**, 074503 (2006). J.L. Kline, E.E. Scime, R.F. Boivin, A.M. Keesee, and X. Sun, Plasma Sources Sci. Technol. **11**, 413 (2002).

GP8.00155 Resonant power absorption experiments on the Radially Localized Helicon mode
, C. LEE, G. CHEN, D. BERISFORD, R. BENGTSON, T. SCARBOROUGH, University of Texas at Austin — We present results of a series of experiments exploring the resonant power absorption as it relates to the Radially Localized Helicon (RLH) mode. We expand on previous work on this field by doing a frequency scan using a second RF generator as a frequency probe. We increase the measured frequency range to include the lower hybrid resonance (LHR) frequency as well frequencies above the driving frequency. The external magnetic field is varied in order to change LHR frequency conditions. Measurements of power absorption are taken using an in-situ RF sensor to measure voltage, current, and phase.

Tuesday, November 13, 2007 9:30AM - 12:30PM –

Session GM4 Mini-conference on Angular Momentum Transport in Laboratory and Nature I

Rosen Centre Hotel Salon 1/2

9:30AM GM4.00001 The angular momentum cycle in tropical cyclones: transport, dissipation, and wave-mean flow interactions
, DAVID NOLAN, University of Miami — Like all strong atmospheric vortices, tropical cyclones (hurricanes) are formed and maintained by the principle of angular momentum conservation. In the developing stage, a net transport of angular momentum into the core region, combined with a contraction of the radius of maximum winds, leads to a large intensification of the vortex. In the mature stage, a quasi-steady balance is maintained between inward transport of angular momentum, loss through the surface due to friction, and a redistribution of angular momentum by both vortex-Rossby waves and inertia-buoyancy waves. When cyclones reach a sufficient strength, these waves can become unstable, leading to a rapid redistribution of angular momentum that ultimately limits the duration of the most intense periods.

10:00AM GM4.00002 Transport by Vortices in Protoplanetary Disks
, PHILIP MARCUS, University of California at Berkeley, JOE BARRANCO, San Francisco State University — We present calculations and analyses of 3D vortices embedded in the vertically-stratified, rotating, shearing environment of a nearly Keplerian accretion disk around a protostar. The vortices can efficiently transport angular momentum radially away from the protostar, enabling mass to accrete on the protostar at rates of approximately one solar mass per million years, or higher. They also are efficient at accumulating dust grains, which is important in planetesimal formation. The vortices are most stable when they are located off the mid-plane of the protoplanetary disk. The 3D vortices are very robust - in part due to the fact that like-signed vortices embedded in a like-signed shear readily merge. The vortices do not require an ad hoc set of arbitrary or unlikely initial conditions. They can form from white noise, but the easiest, and probably most plausible, way in which they form is from internal gravity waves. Simulations show that almost any type of perturbation fills the disk with inertial-gravity waves. The waves "break" when they get too far from the disk mid-plane, and then form intense vortices, which readily merge together if they are anticyclonic.

10:30AM GM4.00003 Theory of momentum transport in rotating/stratified HD and MHD turbulence[1]
, EUN-JIN KIM, N LEPROVOST, Univ. of Sheffield — The importance of magnetic fields, rotation, and stratification in momentum transport cannot be overemphasized. They excite waves in the system, which modify the property of turbulence, with a crucial effect on transport. Indeed, one of the main difficulties in stellar rotational evolution theory has been the lack of a consistent theory of momentum transport incorporating complex physical interactions between turbulence, waves, and shear flow. In particular, while shear flow is often considered to be a source of turbulence, the effect of stable shear flow on regulating turbulence has been totally ignored in traditional modelling. Here, we first show that shear flows can quench turbulence, leading to weak, anisotropic turbulence and momentum transport [1]. Strong anisotropy caused by shear flow leads to non-diffusive momentum transport (like alpha effect in dynamos) in rotating turbulence [2]. Furthermore, in strongly stratified medium, momentum transport becomes anti-diffusive, with negative eddy viscosity, offering a mechanism for the formation of layer-like structure. The effect of magnetic field on transport reduction by the cancellation of Reynolds stress by Maxwell stress is demonstrated [3]. [1] N. Leprovost and E. Kim, A&A, 456, 617 (2006) [2] N. Leprovost and E. Kim, A&A, L654, 1166 (2007) [3] E. Kim and N. Leprovost, A&A, 468, 1025 (2007); 465, 633 (2007)

[1]This is supported by UK PPARC Grant PP/B501512/1

10:50AM GM4.00004 Angular Momentum Transport Studies Relevant to Astrophysical Accretion Disks with the Princeton MagnetoRotational Instability Experiment
, ETHAN SCHARTMAN, MARK NORNBERG, HANTAO JI, PPPL, CMSO, MICHAEL J. BURIN, California State University, San Marcos, JEREMY GOODMAN, Princeton University — Observationally-inferred rates of angular momentum transport in accretion disks are too large to be explained by a non-turbulent viscosity. Investigation of vertically-thin disks has focused on two sources of instability to drive a turbulent viscosity: the MagnetoRotational Instability (MRI) and Subcritical Hydrodynamic Instability (SHI). In MRI, a weak ambient magnetic field linearly destabilizes otherwise neutral hydrodynamic displacements. In SHI, transient amplification of linear disturbances by the differential rotation allows access to non-linearly unstable modes. The Princeton MRI experiment investigates both instabilities. It consists of a Couette-Taylor apparatus which uses water or liquid Gallium alloy to reliably generate rotating flows with linear stability properties analagous to astrophysical disks. In contrast to previous claims, we find no evidence of SHI in water at Reynolds numbers of order one million. We argue that SHI cannot provide astrophysically relevant rates of angular momentum transport. Our hydrodynamically stable flows provide an opportunity to make a conclusive detection of the MRI. The first results of our search for the MRI will be presented. Supported by DOE, NSF and NASA.

11:10AM GM4.00005 Numerical simulations of magneto-rotational turbulence in cylindrical geometry.[1]
, FAUSTO CATTANEO, University of Chicago / Argonne National Laboratory, PAUL FISCHER, Argonne National Laboratory, ALEKSANDR OBABKO, University of Chicago — We present numerical simulations of magneto-rotational flows in cylindrical Couette geometry. To the best of our knowledge these simulations are the most highly resolved in this geometry to date. We study regimes in which the magneto-rotational instability is strongly supercritical, and its nonlinear evolution leads to the development of turbulence. We show that in these regimes, the flows act as efficient dynamos and the turbulence persists even in the absence of an externally imposed magnetic field. The mechanism responsible for the saturation amplitude of the turbulence involves both an increase in dissipation and a modification of the background rotational profile. The angular momentum transport is mostly by the Maxwell stresses, and is enhanced from its collisional value by a factor of the order the Reynolds number of the fluctuating velocity.

[1]This work is supported by the NSF sponsored Center for Magnetic Self-Organization

11:40AM GM4.00006 Experimental results on the magnetorotational instability in helical magnetic fields , FRANK STEFANI, THOMAS GUNDRUM, GUNTER GERBETH, Forschungszentrum Dresden-Rossendorf, GÜNTHER RÜDIGER, JACEK SZKLARSKI, Astrophysikalisches Institut Potsdam, RAINER HOLLERBACH, University of Leeds — The magnetorotational instability (MRI) is believed to play a crucial role in the formation of stars and black holes. By destabilizing otherwise stable Keplerian flows, the MRI enables outward transport of angular momentum in accretion discs which is a necessity for the growth of the central objects. Usually, MRI is investigated under the assumption of an externally applied axial magnetic field. However, the effort to investigate the MRI in a liquid metal experiment can be dramatically reduced if the purely axial magnetic field is replaced by a helical magnetic field. We summarize the results of a various Taylor-Couette experiments [1,2,3] with the liquid metallic alloy GaInSn under the influence of helical magnetic fields that show typical features of MRI at Reynolds numbers of the order 1000 and Hartmann nubers of the order 10.

[1] F. Stefani et al. (2006), Phys. Rev. Lett. 97, 184502.
[2] G. Rüdiger et al. (2006), Astrophys. J. 649 (2006), L145-L147.
[3] F. Stefani et al. (2007), New J. Phys. (2007), in press; astro-ph/0701030.

12:10PM GM4.00007 Axisymmetric Numerical and Analytical Studies of the Helical Magnetorotational Instability in a Magnetized Taylor-Couette Flow[1] , WEI LIU, CMSO, PPPL, JEREMY GOODMAN, Princeton University, HANTAO JI, CMSO, PPPL — Recently, Hollerbach and Rüdiger have reported that MRI modes may grow at much reduced R_{m} and S in the presence of a helical background field, a current-free combination of axial and toroidal field. We have investigated these helical MRI modes. In vertically infinite or periodic cylinders, resistive HMRI is a weakly destabilized hydrodynamic inertial oscillation propagating axially along the background Poynting flux. Growth rates are small, however, and require large axial currents. The new mode is stable in Keplerian flow profiles regardless of end conditions. Furthermore, inviscid studies show finite cylinders with insulating endcaps reduce the growth rate and stabilize highly resistive flows entirely, which conflicts with the PROMISE observation at low magnetic Reynolds number. However, in viscous simulations, by accurately modeling all viscous and magnetic boundaries, we reproduce the measured wave patterns and their amplitudes. Contrary to previous claims, the waves are shown to be transiently amplified disturbances launched by viscous boundary layers rather than globally unstable magnetorotational modes.

[1]supported by DoE, NASA and NSF.

Tuesday, November 13, 2007 9:30AM - 11:10AM –

Session GM5 Mini-conference on Optimizing Helicon Source Performance-Absorption and Heating Mechanisms Rosen Centre Hotel Salon 11/12

9:30AM GM5.00001 Helicon Sources: Why they work , ROD BOSWELL, Australian National University, SPACE PLASMA POWER AND PROPULSION TEAM — A helicon source is a cylindrical ceramic tube containing a gas in the milliTorr region immersed in an axial magnet field surrounded at some region by an antenna fed with rf around 10 MHz. As the power is increased it will show a variety of modes characterised by changes in the plasma density. Low power produces a spatially uniform capacitive discharge with the electric field heating the electrons: at higher power the discharge can show a jump (with hysteresis) into an inductive mode when the skin depth enters the plasma that5 produces an annular plasma: powers around a kilowatt produce centrally peaked plasmas of densities $\sim 10^{12}$ cm^{-3} where optical measurements show bursts of electrons traveling with the helicon velocity, consistent with acceleration by the E_z fields of the m=1 mode. At higher densities, when the plasma enters the "blue mode", the coulomb mean free path becomes sufficiently small that the plasma becomes resistive and the helicon damps linearly. Other electron heating proposals are discussed and compared to experiment.

9:50AM GM5.00002 Magnetic Field Dependencies in the Mini-RFTF Light Ion Helicon Plasma Source[1] , R.H. GOULDING, F.W. BAITY, D.A. RASMUSSEN, D.O. SPARKS, Oak Ridge National Laboratory, M.D. CARTER, Ad Astra Rocket Company, M. YOSHITAKA, Graduate School for Creation of New Photonics Industries — For several years hydrogen plasmas have been produced in the Mini-RFTF Light Ion Helicon device with densities ($\leq 2.5 \times 10^{19} m^{-3}$) comparable to those commonly observed in helicon devices using heavier ion species for comparable input powers (1-5 kW). The use of light ions including hydrogen and helium has allowed the continuous range of regimes $\omega < \omega_{LH}$ to $\omega > \omega_{LH}$, where ω_{LH} is the lower hybrid frequency, to be carefully explored at modest magnetic field strength. A detailed set of electron density and rf $\tilde{B}$ measurements with widely varying —B— at the antenna strongly suggest that in the case of this device, collisional damping of the fast (helicon) wave, with the electric field strength enhanced by the presence of eigenmodes, is responsible for the efficient power coupling to the plasma. The lower hybrid frequency has been shown not to play an important role, at least during equilibrium operation. The extensive evidence in support of these findings will be reviewed

[1]Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

10:10AM GM5.00003 Density and temperature maxima at specific w and B , MATTHEW BALKEY, LANL, EARL E. SCIME, West Virginia University, JOHN L. KLINE, PAUL KEITER, LANL, ROBERT BOIVIN, Auburn University — We report measurements of electron density and perpendicular ion temperatures as a function of driving frequency and magnetic field strength in an argon helicon plasma for five different RF antennas: a Nagoya type III antenna, a "Boswell" saddle coil antenna, a 19 cm long m=+1 helical antenna, a 30 cm long m=+1 helical antenna, and a 19 cm long m=+1 helical antenna with narrow straps. The experimental results clearly indicate that for all antennas, the electron density is maximized at a significantly different RF frequency than the frequency, which yields the maximum ion temperature. Ion temperatures in excess of 1 eV for 750 W of input power are observed. These results suggest that the mechanisms responsible for coupling energy into the ions and electrons are distinct and therefore helicon sources can be configured to maximize electron density without simultaneously maximizing the perpendicular ion temperature.

10:30AM GM5.00004 Radially localized helicon mode and power deposition in a helicon source , GUANGYE CHEN, ALEXEY AREFIEV, ROGER BENGTSON, BORIS BREIZMAN, CHARLES LEE, LAXMINARAYAN RAJA, The University of Texas at Austin — Radially localized helicon (RLH) modes [1] arise in a magnetized plasma with a density gradient across the confining magnetic field. The density gradient modifies the dispersion relation of conventional helicon waves, so that the resulting eigenfrequency of an RLH mode is much lower than that of a conventional helicon wave in an elongated plasma under similar conditions. This work presents evidence that RLH waves play a significant role in helicon plasma sources. Plasma density profile was measured in an argon helicon discharge driven by a 1 kW power supply at 13.56 MHz through a half-turn helical antenna. The experimentally measured density profile was then used to calculate the rf field structure. It is found that RLH waves with an azimuthal wave number m=1 form a standing wave structure in the axial direction and that the frequency of the RLH eigenmode is close to the driving frequency of the rf antenna. The calculated resonant power absorption, associated with the RLH eigenmode, accounts for most of the rf power deposited into the plasma in the experiment. The power deposited via TG modes does not exceed 10% of the total power absorption.

[1] B. N. Breizman and A. V. Arefiev, Phys. Rev. Lett. 84, 3863 (2000).

10:50AM GM5.00005 Helicon mode formation and rf power deposition in a helicon source, MICHAEL KRAEMER, KARI NIEMI, Ruhr University Bochum — The nonlinear nature of the rf absorption in a helicon-produced plasma was investigated on the helicon device HE-L [1] with the aid of a double pulse technique providing high and low amplitude helicon propagation under nearly identical conditions. Time- and space-resolved (2D) measurements of the rf magnetic field (amplitude and phase of all components) were carried out by means of a B-dot probe array. For high rf power, a small narrow peak arises on top of the density profile close to the axis leading to focusing of the rf field energy and the rf power deposition. Nevertheless, in accordance with the linear helicon theory for a non-uniform plasma, the axial wavenumber remains nearly the same as for low power. The rf power deposition in the core of the helicon discharge deduced from the energy flux balance was compared with that obtained from the rf field distribution assuming collisional absorption. It turns out that collisions are by far not sufficient to account for the absorption of helicon modes, particularly for high rf power. Nonlinear processes, most likely associated with the parametric excitation of electrostatic fluctuations [2], are thus involved.- This work was supported by the Deutsche Forschungsgemeinschaft (Sonderforschungsbereich 591, Project A7).- [1] M. Krämer, B. Lorenz, B. Clarenbach, Plasma Sources Sci. Technol. 11A (2002) 120. [2] B. Lorenz, M. Krämer, V.L. Selenin, Yu.M. Aliev, Plasma Sources Sci. Technol. 14, 623 (2005).

Tuesday, November 13, 2007 2:00PM - 5:00PM –

Session JI1 Waves and Energetic Particles Rosen Centre Hotel Junior Ballroom

2:00PM JI1.00001 Excitation of Alfvén Eigenmodes by Low Velocity Beam Ions in the JET and DIII-D Tokamaks[1], R. NAZIKIAN, Princeton Plasma Physics Laboratory — New data on the DIII-D and JET tokamaks reveal a rich variety of Alfvénic activity excited by neutral beam ions traveling at only a small fraction of the local Alfvén velocity. These observations challenge our detailed understanding of the excitation of Alfvénic phenomena and provide a validation platform for testing fundamental theoretical predictions. In addition, precise internal measurements of density and temperature fluctuations reveal new information on the kinetic properties of Alfvén eigenmodes that challenge ideal MHD descriptions of these instabilities. Recent experiments on the JET facility with 3.5 T magnetic field and low plasma density demonstrate that Cascade modes are excited by 50 keV beam ions corresponding to only $v_A/6$, where v_A is the local Alfvén velocity. Toroidal Alfvén eigenmodes are excited by ions traveling at only $v_A/4$, well below the $v_A/3$ sideband condition for the primary resonance. Detailed stability analysis reveals a key role played by finite orbit effects and in particular the beam ion anisotropy for these low energy excitations. Similarly, studies on DIII-D with 2.0 T magnetic fields reveal that the direction of injection of neutral beam injection is a critical factor in the excitation of Alfvén eigenmodes. As in JET, a key to directional sensitivity is the finite orbit width of the fast ions. New observations are also obtained on the excitation of n=0 modes in both JET and DIII-D driven by low energy (50-80 keV) beam ions. Internal measurements reveal much smaller temperature-to-density fluctuation levels for these modes, suggesting that the fluctuations cannot be interpreted as due to the radial displacement of magnetic field lines.

[1]Supported by US DOE under DE-AC02-76CH03073 and DE-FC02-04ER54698 and the EFDA JET program.

2:30PM JI1.00002 Alfvén Cascade modes at high β_e in the National Spherical Torus Experiment–structure and suppression[1], NEAL A. CROCKER, UCLA — Beam ions and/or fusion alphas are expected to excite Alfvén Cascade (AC) modes (i.e. reversed-shear Alfvén eigenmodes) in ITER reversed-shear advanced scenarios. The National Spherical Torus eXperiment (NSTX), where fast-ions with comparable $v/v_{Alfv\acute{e}n}$ ($\sim 2-4$) excite ACs, is an ideal device in which to observe ACs and their impact. Its wide range of β_e(ratio of electron to magnetic pressure) enables tests of AC theory up to, and beyond, a critical β_e where suppression is predicted. A value for critical β_e, $\sim [4q_{min}^2 o1+(7/4)(T_i/T_e))]^{-1}$, may be derived from the theory of Breizman, et al. [*Phys. Plasmas* **12** *(2005) 112506*]. Observations of suppression and frequency evolution in NSTX, including onset and saturation, agree well with this theory and calculations by the NOVA-K linear stability code. The dependence of AC frequency on minimum safety factor (q_{min}) enables a sensitive determination of q_{min} from the AC spectrum that agrees well with the minimum of the q profile measured using the motional Stark effect. AC structure measurements near critical β_e from three fixed frequency (i.e. spatially localized) reflectometers and three tangential interferometers show a structure consistent with predicted localization near the q_{min} radius. Magnetic measurements indicate shear-wave polarization at q_{min}. Fast-ion response is monitored with neutral particle analyzers, a fast lost ion probe and neutron detectors. Profile measurements of q, density, electron and ion temperature, and rotation are used by NOVA-K to predict mode structure and frequency, or suppression, for direct comparison with the mode measurements. These novel observations of ACs near critical β_e are well explained by theory, allowing us to extrapolate our understanding of this physics with confidence.

[1]Supported by U.S. DOE Contract # DE-FG03-99ER54527 and DE-AC02-76CH03073

3:00PM JI1.00003 Lower Hybrid Current Drive Experiments on Alcator C-Mod: Comparison with Theory and Simulation[1], PAUL BONOLI, MIT - Plasma Science and Fusion Center — Recently, lower hybrid current drive (LHCD) experiments have been carried out on Alcator C-Mod using an RF system consisting of 12 klystrons at 4.6 GHz, feeding a 4 × 22 waveguide array. Up to 900 kW of LH power has been coupled in the range$1.6 \leq n_{//} \leq 4$), where $n_{//}$is the parallel refractive index. Driven LH currents have been inferred from magnetic measurements by extrapolating to zero loop voltage, yielding an efficiency of $n_{20}I_{LH}R/P_{LH} \approx 0.3$ [1]. We have simulated the LH current drive in these discharges using the combined ray tracing / 3D (r, $v_\perp$, $v_{//}$) Fokker Planck code GENRAY – CQL3D [2] and found similar current drive efficiencies. Measurements of nonthermal x-ray emission and electron cyclotron emission (ECE) confirm the presence of a significant fast electron population that varies with waveguide phasing and plasma density. Studies are currently underway to investigate the role of fast electron diffusion and full-wave effects such as diffractional broadening in determining the spatial and velocity space structure of the nonthermal electrons. The 3D (r, $v_\perp$, $v_{//}$) electron distribution function from CQL3D has been used in synthetic diagnostic codes to simulate the measured hard x-ray and ECE emissions. Fast electron diffusion times have been inferred from x-ray data by employing a radial diffusion operator in CQL3D and determining the fast electron diffusivities that are required to reproduce the experimentally observed profiles of hard x-ray emission. Finally, we have been performing full-wave LH field simulations using the massively parallel TORIC –LH solver [3] in order to assess spatial and spectral broadening of the incident wave front that can result from diffraction and wave focusing effects.

[1] R. Parker, Bull. Am. Phys. Soc. **51**, 20 (2006).
[2] R.W. Harvey and M. McCoy, "The CQL3D Fokker Planck Code," *Proc. IAEA Tech. Comm. Meeting on Simulation and Modeling of Thermonuclear Plasmas*, Montreal, Canada, 1992.
[3] J. C. Wright *et al.*, Nucl. Fusion **45**, 1411 (2005).

[1]Work done in collaboration with the Alcator C-Mod Team and the SciDAC Center for Simulation of Wave-Plasma Interactions. Work Supported by the US Department of Energy.

3:30PM JI1.00004 ICRF performance with Metallic Plasma Facing Components: Revenge of the Sheath[1] , STEPHEN WUKITCH, MIT Plasma Science and Fusion Center — Ion cyclotron range of frequency (ICRF) heating is expected to provide auxiliary heating for ITER and future fusion reactors where high Z metallic plasma facing components (PFCs) are envisioned. The advantages of ICRF heating is the availability of relatively inexpensive high power sources and it can directly heat ions. For coupling, the antenna needs to be close to the plasma and antenna operation can be limited by compatibility (impurity generation, density production and erosion). Utilizing high Z PFCs, control of ICRF generated impurities becomes more important because the acceptable fractional high Z material concentration in the plasma is of order 1000 times less than low Z materials. In addition, low Z coatings applied in-situ, ie boronization, is often utilized to mitigate the high Z impurities in the plasma. However, erosion of these typically thin, low Z coatings will limit their effective lifetime. In Alcator C-Mod, we have investigated the compatibility of high power ICRF heating with high performance plasmas and high-Z PFCs with and without boronization. With boronization, record C-Mod stored energy and world record plasma pressures were achieved with 5.25 MW of injected ICRF power. However, impurity control through boronization is temporary and boronization appears to erode 3-5 times faster with ICRF compared with Ohmic H-modes. Experimental evidence suggests that RF-enhanced sheaths on open field lines are responsible for enhanced erosion and impurity influx. Utilizing localized boronization, we have determined that the primary impurity source is outside the divertor and we demonstrated that the erosion location is linked to the active antenna. Furthermore, we observed that erosion rate associated with ICRF heating was unaffected by the heating scenario's single pass absorption. Using a 3-D antenna code coupled to a full wave solver we will present the influence antenna geometry has upon sheaths and possible mitigation strategies.

[1]Work supported by US DoE Cooperative agreement DE-FC02-99ER54512.

4:00PM JI1.00005 HHFW Heating Efficiency and Current Drive Enhancement at Longer Wavelengths on NSTX[1] , JOEL HOSEA, Princeton Plasma Physics Laboratory — High harmonic fast wave (HHFW) heating and current drive (CD) are being developed on NSTX for supporting startup and sustainment of the ST plasma. Considerable enhancement of the core heating efficiency (η) under CD conditions has been demonstrated, correlating strongly with locating the onset density for fast wave perpendicular propagation – $n_{onset} \propto B_\phi \times k_{||}^2/\omega$ – away from the antenna/wall. FW fields propagating close to the wall with decreasing B_ϕ and $k_{||}$ could enhance both parametric decay instability (PDI) losses and losses in sheaths and structures around the machine. HHFW RF power delivered to the core plasma of NSTX is strongly reduced as $k_{||}$ is reduced – for B_Φ= 4.5kG, heating is $\sim 1/2$ as effective at k_ϕ= - 7m^{-1} as at 14 m^{-1} and $\sim 1/10$ as effective at - 3m^{-1}. A dramatic increase in η is observed for k_ϕ - 7m^{-1} when B_ϕ is increased to 5.5 kG (central T_e near 4 keV at P_{RF} = 2 MW), when the density 2 cm in front of the antenna is at or below n_{onset}. However, η is not improved when the density immediately in front of the antenna is elevated relative to the onset value. Furthermore, η at even lower k_ϕ still falls off rapidly with the $k_\phi$value. Measured edge ion heating, attributable to PDI, does not change significantly with B_ϕ and thus the improvement in $\eta$is attributed to a reduction of surface FW losses. This work is important for understanding the role of perpendicular propagation of fast waves near the antenna/wall on surface power losses generally, and has important implications for FW heating efficiency in the standard minority regimes as well. For example, the antenna bombardment observed for $k_{||}$ near zero excitation on TFTR can be attributed to n_{onset} being exceeded at the antenna face. Improved detection of CD effects under conditions of higher coupling efficiency on NSTX will be presented.

[1]Collaborators: The NSTX Team. This work was supported by US DOE Contract No. DE-AC02-76CH03073.

4:30PM JI1.00006 EBW harmonic generation in heating and current drive[1] , JOHN CARY, University of Colorado — Experiments on MST and NSTX are using or proposing to use electron Bernstein waves (EBWs) for heating and current drive, as these modes can couple into the overdense, high-beta plasmas via X-B or O-X-B mode conversions. This work shows that for modest power - typical of those planned for experiments - significant energy can be transferred from the fundamental mode to its harmonic. This arises because of the existence of a resonant point, where both the frequency and wave number match for the fundamental and its harmonic. This resonant point can occur where the harmonic has zero group velocity, hence it is weakly stabilized by propagation, and large power transfer occurs. The required pump power is much lower than the electron thermal energy. It is found that the amplitude of the second harmonic EBW excited can exceed that of the fundamental wave with the plasma and wave parameters used in the experiments. The system is investigated both analytically and through use of the VORPAL computing framework, with the latter via both via both the delta-f and full particle-in-cell (PIC) simulations, which confirm the analytical predictions. This second harmonic EBW generation can cause the wave power absorbed near the resonance layer at the half-harmonic frequencies and thus affect EBW power deposition significantly.

[1]This work was carried out in collaboration with Nong Xiang and was supported by the US Department of Energy under grant no. DE-FG02-04ER54735

Tuesday, November 13, 2007 2:00PM - 3:00PM –
Session JT2 Tutorial: Plasma-Facing Materials Rosen Centre Hotel Salon 3/4

2:00PM JT2.00001 Multiscale Physics Challenges For Plasma-Facing Materials[1] , NASR GHONIEM, University of California at Los Angeles — Plasma-facing materials undoubtedly experience some of the most demanding environments ever encountered by functional materials in engineered systems. They will be subjected to extremes of heat flux, ion and electromagnetic radiation bombardment, and neutron irradiation. The microstructure and hence all properties of the first few microns will be in a dynamic state, and will continuously evolve and change as the material is used in the plasma chamber. Several physical effects must be considered in the design and utilization of plasma-facing components, such as sputtering, erosion, re-deposition, de-gasing, blistering, embrittlement, and loss of ductility. Because of the severity of the operational environment, the development of plasma-facing materials must be based on the fundamental principles of physics, mechanics and materials science. We discuss here the multiscale modeling approach to the development of plasma-facing materials and components. The framework starts at the atomistic length scale, and utilizes both ab initio, molecular dynamics and kinetic Monte Carlo techniques. At the intermediate scale between the atomistic and continuum, mesoscopic methods (e.g. dislocation dynamics) are developed to describe the evolution of the materials microstructure. Finally, continuum methods are used to connect to experimental investigations. It will be shown that the proposed multiscale modeling framework, verified by experiments at each length scale, will lead to robust and rational development of reliable materials.
Research is supported by the US Department of Energy, Office of Fusion Energy, under grant #DE-FG02-03ER5470 with UCLA.

[1]Collaborators: B. Wirth (UCB), G.R. Odette (UCSB), R. Kurtz (PNNL), R. Stoller (ORNL), S. Zinkle (ORNL), Y. Osetskiy (ORNL), and S. Sharafat (UCLA).

Tuesday, November 13, 2007 2:00PM - 5:00PM –
Session JO3 Compression and Burn II Rosen Centre Hotel Salon 9/10

2:00PM JO3.00001 High-Areal-Density Cryogenic D_2 Implosions on OMEGA , T.C. SANGSTER, V.N. GONCHAROV, P.B. RADHA, V.A. SMALYUK, R. BETTI, R.S. CRAXTON, J.A. DELETTREZ, D.H. EDGELL, V.YU. GLEBOV, D.R. HARDING, J.P. KNAUER, F.J. MARSHALL, R.L. MCCRORY, P.W. MCKENTY, D.D. MEYERHOFER, S.P. REGAN, W. SEKA, S. SKUPSKY, J.M. SOURES, C. STOECKL, B. YAAKOBI, Laboratory for Laser Energetics, U. of Rochester, J.A. FRENJE, R.D. PETRASSO, PSFC, MIT, D. SHVARTS, NRCN — The validation of direct-drive ignition target designs on OMEGA requires the demonstration of both 1-D burn and 1-D areal density (ρR) up to the point of mix truncation with cryogenic fuel on an adiabat of $\leq$4 and a peak implosion velocity of $\sim$3.5 $\times$ 10^7 cm/s. We report here on the demonstration of 1-D ρR in a series of cryogenic D_2 implosions with a fuel adiabat of $\sim$2. The targets consisted of a thick CD ablator (10-μm wall) and a fuel layer of $\sim$95 μm of D_2. The inner-surface roughness of the ice was $\sim$2-μm rms. With an 18-kJ decaying shock drive pulse with a peak intensity of 5 $\times$ 10^{14} W/cm^2, the $\langle \rho R \rangle$ was 202 mg/cm^2 (95% of 1-D). The thick CD ablator mitigates hot electron preheat from the two-plasmon-decay instability in hydrogen—by design, no hydrogen reaches the quarter-critical density surface. Future experiments will focus on areal density performance at higher implosion velocities. This work was supported by the U.S. DOE Office of ICF under Cooperative Agreement DE-FC52-92SF19460.

2:12PM JO3.00002 Using Radiation Preheat to Improve Shell Stability in OMEGA Implosions , P.B. RADHA, J.P. KNAUER, T.C. SANGSTER, V.N. GONCHAROV, I.V. IGUMENSCHEV, R. BETTI, R. EPSTEIN, D.D. MEYERHOFER, S. SKUPSKY, Laboratory for Laser Energetics, U. of Rochester — Preheat of imploding shells from coronal photons in direct-drive implosions has been previously proposed to shape the adiabat in the shell and reduce ablative Rayleigh–Taylor growth rates during acceleration.[1] OMEGA cryogenic and warm plastic designs with Si-doped ablators are studied using one- and two-dimensional simulations. The effect on compression, single-mode growth rates, and shell distortions are examined. Areal density, which primarily depends on the inner-shell adiabat, is a sensitive measure of preheat of the inner fuel. Simulation results will be compared with observations of areal densities in OMEGA implosions. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] S. E. Bodner *et al.*, Phys. Plasmas **5**, 1901 (1998).

2:24PM JO3.00003 Transport of Energetic Electrons Produced from Two-Plasmon Decay in the 1-D Hydrodynamic Code *LILAC* , J.A. DELETTREZ, V.N. GONCHAROV, P.B. RADHA, C. STOECKL, A.V. MAXIMOV, T.C. SANGSTER, Laboratory for Laser Energetics, U. of Rochester, J.A. FRENJE, PSFC, MIT, D. SHVARTS, NRCN — The effect of two-plasmon-decay electrons on the implosion of cryogenic targets has been the subject of intense scrutiny at the Laboratory for Laser Energetics. Preheat of the fuel caused by these electrons can reduce the maximum areal density attainable at stagnation. The electrons are created at the quarter-critical surface when a threshold depending on laser intensity and local thermal electron scale length is attained. The fraction of laser energy absorbed is a parameter that depends exponentially on the threshold condition and saturates at laser intensities of 10^{15} W/cm^2. The source distribution is Maxwellian with a temperature scaling inferred from the measurement of hard x rays. The electrons are transported with a multigroup diffusion model in which the free-streaming electrons are treated by a modified P_2 model. Simulation results from warm plastic and cryogenic implosions are compared with the following experimental diagnostics: the hard-x-ray temporal and time-integrated emission, the fast-ion spectrum, and the neutron-averaged areal density at stagnation. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

2:36PM JO3.00004 X-Ray Spectral Measurements of Cryogenic Capsules Imploded by OMEGA , F.J. MARSHALL, J.P. KNAUER, T.C. SANGSTER, J.A. DELETTREZ, P.W. MCKENTY, R. EPSTEIN, V.N. GONCHAROV, B. YAAKOBI, Laboratory for Laser Energetics, U. of Rochester — A set of absolutely calibrated, x-ray imaging systems have been used to measure the emergent x-ray spectra from cryogenic D_2- and DT-filled capsules imploded by the OMEGA UV Laser System. The imaging systems include both pinholes and Kirkpatrick–Baez microscopes, all dispersed by transmission gratings. The shapes of the observed spectra allow for inference of the core electron temperature (kT_e) and in selected cases the surrounding main-fuel-layer areal density (ρR_{fuel}). The latter determination is dependent on the assumed temperature and density in the fuel layer and hence can only place bounds on the quantity ρR_{fuel}. Comparisons of these measurements with both one- and two-dimensional hydrocode simulations are used in part to evaluate the performance of these implosions. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

2:48PM JO3.00005 Radiative Transport Modeling Relevant to Cryogenic Implosion Simulation and Diagnosis , R. EPSTEIN, J.A. DELETTREZ, V.N. GONCHAROV, J.P. KNAUER, P.W. MCKENTY, F.J. MARSHALL, P.B. RADHA, S.P. REGAN, H. SAWADA, B. YAAKOBI, Laboratory for Laser Energetics, U. of Rochester — The design of OMEGA cryogenic implosion experiments relies in part on modeling radiative preheat, one method of improving the hydrodynamic stability of the imploding shell. Diagnosing the core temperature and shell density near peak compression relies in part on modeling shell-absorption spectroscopy. Important elements of our modeling, including atomic physics approximations, high-density physics, transport methods, and multidimensional hydrodynamic effects are identified, and their impact on the accuracy of the radiative transport simulation and on the interpretation of the measured spectra are considered. Simulation results are compared with observed spectra from both the ablative preheat and the core emission phases of the implosions. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460.

3:00PM JO3.00006 Nonlocal Ion-Heat Transport and Viscosity in ICF Implosions Using a Quasi-Monte Carlo Approach , S. SKUPSKY, V.N. GONCHAROV, D. LI, Laboratory for Laser Energetics, U. of Rochester — During shock propagation and coalescence in the vapor region of ICF targets, the ion mean free path can become large compared to relevant spatial scale lengths and to the size of computational cells in computer models. During this time, a local treatment of heat conduction and viscosity is not valid. To investigate the effect of these long mean-free-path ions, two different models (based on Monte Carlo and kinetic techniques) have been developed to treat the nonlocal ion transport, and they have been applied to the modeling of experiments on the OMEGA laser. This presentation will focus on the quasi-Monte-Carlo approach in which ions are tracked through the plasma, and energy and momentum are deposited nonlocally. The following paper (D. Li) will discuss the quasi-kinetic approach. Comparison of the results will be presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

3:12PM JO3.00007 Modeling Ion Heat Transport in ICF Targets , D. LI, V.N. GONCHAROV, I.V. IGUMENSHCHEV, S. SKUPSKY, Laboratory for Laser Energetics, U. of Rochester — This talk will describe the kinetic model used to treat the nonlocal ion heat flux and viscosity in ICF implosions. The model is based on the solution of a simplified Boltzman equation using the Krook approximation. Such an approach was successfully used to calculate nonlocal electron conduction.[1] The model is implemented in the 1-D hydrocode *LILAC*. The results of simulations and comparison with the experimental data will be presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] V. N. Goncharov, Phys. Plasmas **13**, 012702 (2006).

3:24PM JO3.00008 Investigation of Shock Heating and Heat-Front Penetration in Direct-Drive Targets Using Absorption Spectroscopy

, H. SAWADA, S.P. REGAN, P.B. RADHA, R. EPSTEIN, V.N. GONCHAROV, D. LI, D.D. MEYERHOFER, V.A. SMALYUK, T.C. SANGSTER, B. YAAKOBI, Laboratory for Laser Energetics, U. of Rochester, R.C. MANCINI, U. of Nevada, Reno — Time-resolved Al $1s$–$2p$ absorption spectroscopy was used to diagnose direct-drive, shock-heated, and compressed planar targets having nearly Fermi-degenerate predicted plasma conditions ($T_e \sim 10$ to 30 eV, $n_e \sim 1$ to 6×10^{23} cm^{-3}). A 50-μm-thick CH foil with a buried Al tracer layer was irradiated with 10^{14} to 10^{15}W/cm^2, and $\sim$1.5 keV x rays from a point source Sm backlighter were transmitted through the drive foil. The measured absorption spectra were modeled with the atomic physics code PrismSPECT to infer T_e and n_e. The shock heating and heat-front penetration were simulated with the 1-D hydrocode *LILAC*, using a flux-limited or nonlocal transport model. Shock-heating observations are consistent with *LILAC* for the lower drive intensity, but there is evidence of preheat for the higher one. The timing of the heat-front penetration is consistent with a time-dependent flux limiter. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

3:36PM JO3.00009 The Effect of Target Mounts in Direct-Drive Implosions on OMEGA

, I.V. IGUMENSHCHEV, V.N. GONCHAROV, F.J. MARSHALL, M.J. BONINO, P.W. MCKENTY, D.D. MEYERHOFER, T.C. SANGSTER, Laboratory for Laser Energetics, U. of Rochester — Two types of target mounts are currently employed in direct-drive-implosion experiments on OMEGA. A silicon-carbon stalk glued normally to the target surface is used in the case of gas-filled plastic capsules, and a C-mount with four spider silks glued to the target surface is used in cryogenic implosion experiments. We use the 2-D radiation hydrodynamic code *DRACO*[1] to study the effects of target mounts in the implosions of capsules. The capsules are $\sim$430-μm radius and driven by nanosecond-time-scale laser pulses with 10 to 25 kJ of total energy. The simulations indicate that the stalk mount can introduce a significant distortion to the hot spot in plastic implosions. The results of these simulations are compared with x-ray experimental images. The glue spots in the C-mount have been found to not significantly perturb cryogenic implosions, and the simulated neutron yield is only marginally affected. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] P. B. Radha *et al.*, Phys. Plasmas **12**, 032702 (2005).

3:48PM JO3.00010 Multidimensional Numerical Investigation of NIF Saturn PDD Designs with 3-D Laser Ray Tracing

, P.W. MCKENTY, R.S. CRAXTON, S. SKUPSKY, J.A. MAROZAS, T.J.B. COLLINS, A. SHVYDKY, D. KELLER, D.D. MEYERHOFER, R.L. MCCRORY, Laboratory for Laser Energetics, U. of Rochester — The Laboratory for Laser Energetics continues to validate the use of the NIF and the LMJ in the x-ray-drive configuration for direct-drive-ignition experiments. Progress in this area indicates that polar direct drive (PDD) is a viable and attractive option for achieving ignition on these megajoule-class laser systems. Recent work has focused on the implementation of the Saturn PDD illumination scheme, which, employing an equatorial CH ring as a plasma lens, attempts to minimize target perturbations due to the absence of the equatorial beams in the x-ray-drive laser configuration. This paper will examine the implementation of the standard "all-DT" direct-drive-ignition design with a fixed CH equatorial ring. Previous work[1] employed 2-D hybrid *SAGE–DRACO* calculations and indicated minimal performance degradation from 1-D results. We will report on recent 2-D hydrodynamic *DRACO* simulations, examining the effects of the Saturn PDD illumination as modeled with fully integrated 3-D ray-trace models. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] R. S. Craxton *et al.*, Phys. Plasmas **12**, 056304 (2005).

4:00PM JO3.00011 Initial Polar-Direct-Drive Designs to Optimize Neutron Yields on the NIF

, R.S. CRAXTON, A.M. COK, P.W. MCKENTY, Laboratory for Laser Energetics, U. of Rochester — Polar-direct-drive (PDD) designs are proposed for producing symmetric implosions of thin-shell, DT-gas–filled targets leading to high fusion neutron yields for neutron diagnostic development. The designs can be used as soon as the National Ignition Facility (NIF) is operational as they work with indirect-drive phase plates. Two-dimensional simulations using the hydrodynamics code *SAGE* have shown that good low-mode uniformity can be obtained by means of appropriately chosen combinations of defocusing and pointing of the beams, including pointing offsets of individual beams within some of the NIF laser beam quads. The optimizations have been carried out for targets with total laser energies ranging from 350 kJ to 1.5 MJ, enabling the optimum defocusing and pointing parameters to be determined through interpolation for any given laser energy in this range. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

4:12PM JO3.00012 Single-Beam Smoothing Requirements for Wetted-Foam, Direct-Drive NIF Ignition Target Designs

, T.J.B. COLLINS, J.A. MAROZAS, P.W. MCKENTY, P.B. RADHA, S. SKUPSKY, J.D. ZUEGEL, Laboratory for Laser Energetics, U. of Rochester — Wetted-foam, direct-drive target designs are a path to high-gain experiments on the National Ignition Facility (NIF). Previous studies have shown that reduction of single-beam nonuniformity is central to target performance of designs incorporating solid CH ablators.[1] It has also been shown that at 1 MJ, even a wetted-foam target with a low IFAR and low acceleration-phase instability requires a minimum of two-dimensional (2-D) smoothing by spectral dispersion (SSD)[2] for ignition.[3] We show the results of 2-D simulations indicating that this is also the case for 1.5-MJ, wetted-foam, direct-drive NIF target designs. Some possible avenues for single-beam smoothing in the absence of 2-D SSD will be briefly presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] P. W. McKenty *et al.*, Phys. Plasmas **8**, 2315 (2001).
[2] S. Skupsky *et al.*, J. Appl. Phys. **66**, 3456 (1989).
[3] T. J. B. Collins *et al.*, Phys. Plasmas **14**, 056308 (2007).

4:24PM JO3.00013 Alternative Laser-Speckle–Smoothing Schemes for NIF Direct-Drive-Ignition Designs

, J.A. MAROZAS, J.D. ZUEGEL, T.J.B. COLLINS, Laboratory for Laser Energetics, U. of Rochester — The National Ignition Facility (NIF) in its current configuration has smoothing by spectral dispersion (SSD) in only one spatial dimension with a single FM modulator. Such smoothing has been shown to be insufficient in providing adequate uniformity for directly driven targets. It may be possible, however, to attain adequate smoothing using different options within the NIF's capabilities. The motivation is to shoot direct-drive or polar-direct-drive (PDD) targets before the full 2-D SSD system is operational. Two-dimensional *DRACO* simulations of PDD targets, utilizing 3-D ray-trace subroutines, will be used to investigate the feasibility of alternative laser-speckle–smoothing options such as multiple FM modulators in 1-D, chirped pickets and defocused beams. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

4:36PM JO3.00014 The Application of Shock Ignition to Various High Gain Target Concepts.[1]

, L.J. PERKINS, K. LAFORTUNE, A. MILES, L. DIVOL, LLNL, G. LOGAN, LBNL, R. BETTI, LLE — Shock-ignition, a new approach [1] for high gain ignition and burn is being studied for several ICF target concepts: *(1) High gain cryogenic IFE targets, driven by lasers or heavy ions, (2) High fusion yield targets for DOE NNSA applications, (3) Simple, non-cryogenic single shell gas targets.* Such concepts could be assessed on NIF following achievement of indirect-drive ignition. In contrast to conventional hotspot ignition, the assembly and ignition phases are separated by imploding a high mass shell at low velocity using a direct drive pulse of modest energy. The assembled fuel is then separately ignited by a strong, spherical shock driven by a late-time high intensity laser spike, timed to reach the axis as the main fuel is stagnating. Because the implosion velocity is significantly less than that required for hotspot ignition, considerably more fuel mass can be assembled for the same kinetic energy in the shell. Like fast ignition, shock ignition can achieve high gains at low drive energy, but has the advantages of needing only a single laser with less demanding timing and focusing.

[1] R.Betti, C.Zhou, K.Anderson, L.J.Perkins, A.Solodov, *Phys Rev. Lett.* **98**, (2007).

[1]Work performed under the auspices of the U.S. DOE by LLNL under contract No. W-7405-Eng-48.

4:48PM JO3.00015 Ten times higher laser ablation efficiency by nonlinear force driven plasma blocks

, HEINRICH HORA, Dept. of Theoretical Physics, Univ. of New South Wales, GEORGE MILEY, Depr. of NPRE, Univ. of IL, U-C Campus — A significant anomaly at ps. TW laser interacting with plasma was observed based on the suppression of relativistic self-focusing [1,2]. Highly directed low temperature plasma blocks (pistons) are generated by acceleration by the nonlinear (ponderomotive) force. This directly converts optical energy into hydrodynamic motion with little thermal loss due to unavoidable collisions. Instead of the usual 5% ablation efficiency for plasma compression using thermalization, this direct energy conversion mechanism permits 50% ablation efficiency as predicted at spherical compression for fusion [3]. From detailed experiments and computations [2] it can be concluded that irradiated DT fuel shells even may not need the initially pre-irradiation generally assumed [3]. The directivity of the imploding shells permits various options for fusion reactions in the compressed plasma.

[1] H. Hora, J. Badziak et al. Opt. Commun. 207, 333 (2002).
[2] H. Hora, J. Badziak et al. Phys. Plasmas 14, 072701 (2007).
[3] H. Hora, Nucl. Inst. and Methods 144, 17 (1977).

Tuesday, November 13, 2007 2:00PM - 5:00PM –

Session JO6 Short Pulse Laser-Plasma Interactions II Rosen Centre Hotel Salon 5/6

2:00PM JO6.00001 Stochastic Heating in High Intensity Laser-Plasma Interaction. Application to the Wake Field Acceleration Process

, ALAIN BOURDIER, XAVIER DAVOINE, MATHIEU DROUIN, LAURENT GREMILLET, ERIK LEFEBVRE, CEA/DAM Ile-de-France, BP12, 91680 Bruyères-le-Châtel, France — Recently, PIC simulations results published by Tajima et al. and Sheng et al. have shown that chaos can play an important role in the efficient electron heating observed in laser-plasma interaction at very high intensities. These results led us to investigate the conditions under which significant stochastic heating is likely to take place. First, we shall consider the dynamics of a single charged particle in the field of a high intensity wave propagating in an unmagnetized vacuum or plasma. In a second part, the effect of a constant homogeneous magnetic field will be discussed. Third, in the case of a plasma interacting with several electromagnetic waves, the use of Chirikov's criterion to predict the conditions favoring stochastic heating will be presented. Finally, it will be shown that when considering a low density plasma interacting with a high intensity wave perturbed by a low intensity counterpropagating wave, stochastic heating can provide electrons with the right momentum for trapping in the wake field and efficient acceleration.

2:12PM JO6.00002 Enhanced Isochoric Heating in High Contrast Laser-Nano-Cone Interactions

, T.E. COWAN, University of Nevada, Reno, J. RASSUCHINE, E. D'HUMIERES, Y. SENTOKU, UNR, S. BATON, P. GILLOU, M. KOENIG, J. FUCHS, P. AUDEBERT, LULI-Ecole Polytechnique, France, R. KODAMA, M. NAKATSUTSUMI, T. NORIMATSU, ILE-Osaka, Japan, D. BATANI, A. MORACE, R. BEDAELLO, University of Milano, INFM, Italy, L. GREMILLET, C. ROUSSEAUX, CEA, Bruyères-le-Châtel, France, F. DORCHIES, C. FOURMENT, J.J. SANTOS, CELIA, Bordeaux, France, S. HANSEN, LLNL — We discuss the interaction of very high-contrast high-intensity laser pulses with sharp-tipped, nanofabricated Cu cone targets (see [1]), using frequency doubled light at the LULI 100 TW laser (λ=0.53 um, I=4x10^{18} W/cm^2). Previous work at 1ω showed that pre-formed plasma, due to ASE, degraded the laser-cone coupling. At 2ω, high-resolution spectroscopy of Cu K_α emission shows high charge states, implying peak temperatures of up to 400 eV, comparable to the smallest reduced mass targets (50 μm dia x 20 μm thick). This implies a new confinement mechanism which, from 2D collisional PIC simulations, is due to self-generated resistive magnetic fields (up to 10 MG) which confine the hot electrons to the tip region of the cone. Supported by Access to Research Infrastructures in the EU Sixth Framework Programme (contract RII3-CT-2003-506350, Laserlab Europe), and UNR DOE/NNSA grant DE-FC52-01NV14050. [1] Y. Sentoku *et al.*, Phys. Plasmas, **11** 3083 (2004).

2:24PM JO6.00003 Isochoric Heating of Reduced Mass Targets by Ultra-Intense Lasers[1]

, S.C. WILKS, A.J. KEMP, D.S. HEY, P.K. PATEL, S. LEPAPE, M.M. MARINAK, P. NEUMAYER, S. GLENZER, Lawrence Livermore National Security, G. GREGORI, Central Laser Facility, CCLRC Rutherford Appleton Laboratory, S.N. CHEN, F. BEG, University of California, San Diego, W.L. KRUER, University of California, Davis — Recent results using a novel target design that allows material high temperature ($\sim$ 1 keV) solid density plasmas to be created using ultra-intense laser pulses will be presented. Layered targets composed of titanium and tamped with aluminum were irradiated with 1< E < 200 Joules, 1 and 10 picosecond laser pulses. Significant increases in temperature over standard foil targets were observed. Using refined energy conservation arguments and coupling of PIC simulation results into a rad-hydro code, theoretical predictions of achievable temperatures are compared against temperatures inferred from experimental data. Predictions for plastic, titanium, and copper targets irradiated by a wide range of laser parameters will also be presented.

[1]This work was performed under the auspice of the Department of Energy under Contract No. W-7405-Eng-48 and by the Laboratory Directed Research and Development (LDRD) Programs 04-ERD-028 and 04-ERD-023.

2:36PM JO6.00004 Laser Heating of Solid Matter by Light Pressure-Driven Shocks at Ultra-Relativistic Intensities[1]

, K.U. AKLI, R.B. STEPHENS, General Atomics, A.J. MACKINNON, P.K. PATEL, M.H. KEY, S.B. HANSEN, A.J. KEMP, Lawrence Livermore National Lab., R.R. FREEMAN, D. CLARK, K. HIGHBERGER, N. PATEL, L. VAN WOERKOM, R. WEBER, The Ohio State U., F. BEG, T. MA, UCSD, D. HEY, UC-Davis, K. LANCASTER, Rutherford Appleton Lab., C. STOECKEL, M. STORM, W. THEOBALD, U. Rochester-LLE — Heating by irradiation of a solid surface in vacuum with 5×10^{20} Wcm^{-2}, 0.8 ps, 1.05 micron wavelength laser light is studied by x-ray spectroscopy of the K-shell emission from thin layers of Ni, Mo and V. A surface layer is heated to $\sim$5 keV with an axial temperature gradient of 0.6 μm scale length. Images of Ni Lyα show the hot region has a $\sim$25 μm diameter. Collisional particle-in-cell simulations based on density profiles from hydro-models suggest that light pressure compresses the preformed plasma and drives a shock into the solid.

[1]Supported by the US DOE under DE-FG02-05ER54834 and W-7405-ENG-48.

2:48PM JO6.00005 ABSTRACT HAS BEEN MOVED TO SESSION GP8 —

3:00PM JO6.00006 ABSTRACT WITHDRAWN —

3:12PM JO6.00007 Heating of buried layer targets by 1ω and 2ω pulses using the HELEN CPA laser , LEE THORNTON, DAVID HOARTY, Plasma Physics Department, AWE Aldermaston, Reading, UK — Targets of plastic with a buried layer of aluminum at different depths were heated using the HELEN CPA laser which irradiated one surface. The emission spectra from the Al were used to infer the conditions in the target by comparing the measured spectra against those generated by the FLY code (whose input was the temperature and density history calculated by a radiation-hydrodynamics code iterated to achieve the best match to the experimental data). Measurements were taken at both a laser wavelength of 1.06 μm and after conversion to 0.53 μm. The laser irradiance was varied between 2 x 10^{17} - 10^{19} W/cm^2 by altering the laser pulselength, energy and wavelength. The data show the plastic target was heated above 200eV to a depth of about 4μm with 1.06 μm P-polarised light. The FLY comparisons indicate the buried layers heated with 0.53 μm light remained near solid density for the duration of the X-ray emission pulse and achieved a peak temperature of 500$\pm$50eV. In the case where the target was heated with 1.06 μm radiation, the density was an order of magnitude lower and the peak temperature achieved was also lower at 320$\pm$50eV. The depth to which the target was heated was similar at the two wavelengths for 0.5ps pulses. In further measurements using 0.53 μm light at similar energies (but using pulses with a FWHM of 2 ps), heating to greater than 200eV was observed to a depth of 8 μm.

3:24PM JO6.00008 Experiments on Self-Guiding Mechanisms of High Power Laser Pulses in a Plasma , JOSEPH RALPH, ARTHUR PAK, KENNETH MARSH, CHRISTOPHER CLAYTON, FANG FANG, UCLA, CHANDRASHEKHAR JOSHI — Recent 3D theory and PIC simulations in the blowout regime, wherein the pondermotive force of laser with a pulse length on the order of a plasma wavelength expels all electrons, has predicted a range of parameter space where stable laser propagation can occur [1]. In this theory, the density depression caused by electron blow out is the dominant mechism responsible for self-guiding. In this paper we examine experimentally and with PIC simulations laser beam guiding of a multi terwatt TiSapphire laser in a supersonic Helium gas jet. Gas jet density was varied from 2*E18 to to 2*E19 and the length of the plasma was varied from 2 to 5 mm using several gas jets with different diameters. Pondermotive and relativistic effects are considerd by varying laser and plasma parameters. Diagnostics include interferometric and Schlieren techniques. Images of the guided mode are taken at the exit of the gas jet. In addition, the forward images were sent to an imaging spectragraph to observe photon deceleration and deceleration [2].

[1] W. Lu, C. Huang, M. Zhou, and M. Tzoufras, F. S. Tsung, W. B. Mori, and T. Katsouleas, Phys. Plasmas **13**, 056709 (2006)
[2] A. E. Pak, J. E. Ralph, K. A. Marsh , C. E. Clayton, F. Fang and C. Joshi, *These Procedings*

3:36PM JO6.00009 Ion Heating in Laser-Plasma Interaction , J. MENDONCA, GOLP — Ion instabilities due to relativistic electron beams in dense plasmas are considered. They can lead to anomalous heating and transport in inertial fusion plasmas. Results obtained using kinetic and fluid models are given. Significant ion growth rates are possible once the plasma electron drift velocity equals or exceeds the ion sound speed. An hybrid model, in which potential energies are introduced in addition to Temperatures, is also described. Energy is deposited into the electron potential energy which is converted to electron temperature by collisions and to ion potential energy by the ion instability, using integrated growth rates. Ion potential energy is then converted into ion temperature by collisions. The implications for fast ignition are discussed.

3:48PM JO6.00010 Heating in short-pulse laser-driven cone-capped wire targets[1] , R.J. MASON, M. WEI, J. KING, F. BEG, R.B. STEPHENS — The 2-D implicit hybrid simulation code e-PLAS has been used to study heating in cone-capped copper wire targets. The code e-PLAS tracks collisional particle-in-cell (PIC) electrons traversing background plasma of collisional Eulerian cold electron and ion fluids. It computes $E-$ and *B-fields* by the Implicit Moment Method [1,2]. In recent experiments [3] at the Vulcan laser facility, sub- picosecond laser pulses at 1.06 μm, and 4.0 x 10^{20} W/cm^2 intensity were focused into thin-walled ($\sim$10 μm) cones attached to copper wires. The wire diameter was varied from 10-40 μm with a typical length of 1 mm. We characterize heating of the wires as a function of their diameters and length, and relate modifications of this heating to changes in the assumed laser-generated hot electron spectrum and directivity. As in recent nail experiments [4], the cones can serve as reservoirs for hot electrons, diverting them from passage down the wires. [1] R. J. Mason, and C. Cranfill, IEEE Trans. Plasma Sci. **PS-14**, 45 (1986). [2] R. J. Mason, J. Comp. Phys. **71,** 429 (1987). [3] J. King et al., to be submitted to Phys. Rev. Lett.. [4] R. J. Mason, M. Wei, F. Beg, R. Stephens, and C. Snell, in Proc. of ICOPS07, Albuquerque, NM, June 17-22, 2007, Talk 7D4.

[1]Research supported by the USDOE under DE-FG02-07ER84723.

4:00PM JO6.00011 Transport of Energy by Laser-Generated Fast Electrons within Cone-wire Targets[1] , J. KING, T. MA, F. BEG, U.C. San Diego, Mechanical and Aerospace Engineering, La Jolla CA, M. KEY, J. KOCH, A. MACKINNON, A. MACPHEE, P. PATEL, Lawrence Livermore National Lab, Livermore CA, R. STEPHENS, General Atomics, San Diego CA, K. AKLI, R. FREEMAN, L. VAN WOERKOM, Ohio State University, Columbus OH, R. HEATHCOTE, K. LANCASTER, P. NORREYS, Rutherford Appleton Lab, Chilton, Oxon, OX11OQX, UK, R. MASON, Research Applications Corp., Los Alamos NM, W. THEOBALD, Laboratory for Laser Energetics, University of Rochester, Rochester NY — Coupling of energy via laser accelerated electrons to 10 to 40μm diameter Cu wires attached to Al cones irradiated by a 500J, 1ps, f/3 focused laser is studied as a surrogate for fast ignition. Cu Ka images were recorded using a Bragg crystal imager. Ka yield was obtained with a single hit CCD and relative intensities in Cu K-shell spectra were recorded with a HOPG crystal spectrometer. Fitting 1D numerical modeling to axial profiles of Ka emission estimates the coupling efficiency and the average temperature of the electrons in the 1D Ohmically inhibited energy transport.

[1] This work was performed under the auspices of U.S. DOE under contracts DE-FC02-04ER54789, DE-FG02-05ER54834, DE-FG03-00ER54606. The authors kindly acknowledge the support of ILSA at LLNL

4:12PM JO6.00012 Studies of Electron Transport Via Transition Radiation , C. BELLEI, S. NAGEL, L. WILLINGALE, S. KNEIP, S.P.D. MANGLES, A.E. DANGOR, Z. NAJMUDIN, K. KRUSHELNICK, Imperial College London, S. KAR, B. DROMEY, K. MARKEY, P. SIMPSON, M. ZEPF, Queen's University of Belfast, R.J. CLARK, J. GREEN, D. NEELY, P. NORREYS, Rutherford Appleton Laboratory, UK, D. CARROLL, P. MCKENNA, University of Strathclyde, Glasgow — Measurements of electron transport through solid targets have been performed at the Vulcan Petawatt Laser Facility (Rutherford Appleton Laboratory, UK) by looking at the second harmonic of the laser frequency (λ_L=1054 nm) emitted at the rear side of the targets. The emission, that we mainly attribute to coherent transition radiation, is not compatible with a ballistic model of electron transport. The possibility of collimation and even coalescence of the relativistic electrons will be discussed. The radiation also exhibits a polarization dependence, consistent with the properties of transition radiation. The possibility of measuring the polarization state of the transition radiation in order to determine the direction of the fast electrons as they cross the plasma-vacuum interface will be further discussed.

4:24PM JO6.00013 Hot electron coupling to dense plasma for fast ignition[1] , ANDREAS KEMP, Lawrence Livermore National Laboratory, HARTMUT RUHL, Universitaet Bochum, YASUHIKO SENTOKU, EMMANUEL DHUMIERES, University of Nevada, Reno, MAX TABAK, Lawrence Livermore National Laboratory — Critical issues for the fast ignition of inertial confinement fusion targets, where pre-compressed fuel is ignited by injection of an intense short laser pulse, are (i) the coupling efficiency of the short pulse to the hot electrons that heat the core and (ii) the transverse beam divergence of those electrons inside the dense plasma, i.e., determining the fraction of hot electron energy that will reach the core. We address these issues using one-, two- and three-dimensional kinetic computer models that include the effect of collisions.

[1]Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48

4:36PM JO6.00014 Measurement of distribution of x-ray polarization degrees caused by anisotropic hot electrons in ultra-high intensity laser produced plasma , Y. INUBUSHI, Y. OKANO, H. NISHIMURA, T. KAI, S. FUJIOKA, Osaka Univ., T. KAWAMURA, Tokyo Tech., D. BATANI, A. MORACE, R. REDAELLI, Univ. Milan, C. FOURMENT, J. SANTOS, G. MALKA, Univ. Bordeaux 1, A. BOSCHERON, A. CASNER, CEA, M. KOENIG, LULI, T. NAKAMURA, T. JOHZAKI, H. NAGATOMO, K. MIMA, Osaka Univ. — In fast-ignition, investigation of the velocity distribution function (VDF) of hot electrons is critical for clarifying energy transport in ultra-high intensity laser-produced plasmas. X-ray polarization spectroscopy is a useful diagnostic tool for measuring the VDF of electrons inside plasma [1, 2]. A new polarization measurement was performed using a laser pulse (10 J in $\sim$1 ps). Chlorinated triple-layer targets were irradiated, and polarization degrees of Cl-Heα line were measured. Obtained distribution of polarization degrees indicates that the VDF is pancake-like shape at the target surface and cigar-like in deep region. Moreover, depolarizations due to isotropic excitation by bulk electrons and elastic collision of bulk electrons, which were predicted by a model calculation [3] and a time-dependent atomic kinetic code [4], was observed. [1] J. C. Kieffer, et al., Phys. Rev. Lett. **68**, 480 (1992), [2] Y. Inubushi, et al., JQSRT **99**, 305 (2006). [3] Y. Inubushi, et al., J. Plasma Fusion Res. **2**, 0013 (2007). [4] T. Kawamura, et al., submitted.

4:48PM JO6.00015 Cross sections with magnetic sublevels of He-like ions for polarized x-ray spectroscopy , T. KAI, ILE, Osaka U., T. KAWAMURA, Tokyo Inst. Tech., S. NAKAZAKI, Univ. Miyazaki, Y. INUBUSHI, H. NISHIMURA, Y. OKANO, T. NAKAMURA, T. JOHZAKI, H. NAGATOMO, S. FUJIOKA, K. MIMA, ILE, Osaka U. — In fast-ignition plasma, energy transport in dense plasma is one of the critical issues. The fast-ignition plasma emits polarized x-rays since the VDF of generated fast electron is anisotropic VDF. Spectroscopy of polarized x-ray is a useful diagnostics for studying the VDF of fast electrons. The time- dependent collisional-radiative atomic kinetics model was developed to analyze the experimental results of polarized Cl-He α line [1]. To examine the model calculation, the cross sections with magnetic sublevels of He-like Cl and Cu ions were calculated [2]. The calculated cross sections with magnetic sublevels for He-like ions will be discussed for polarized x- ray spectroscopy in the ultrahigh-intense laser (10^{17} 10^{20} W/cm^2).
[1] T. Kai, et al., HEDP 3, 131 (2007); T. Kawamura et al., submitted.
[2] T. Kai, et al., PRA 75, 012703 (2007). ibit, 75, 062710 (2007).

Tuesday, November 13, 2007 2:00PM - 5:00PM – Session JO7 Dusty and Complex Plasmas Rosen Centre Hotel Salon 7/8

2:00PM JO7.00001 Γ , G. MORFILL, Max Planck Institute — Γ, the ratio interaction energy to kinetic energy, is a key quantity in strongly coupled plasma physics. Unfortunately it is also one of the most difficult properties to measure -especially locally at the kinetic level. We combine theory, numerical simulations and experimental results to show how to measure this important quantity in 'complex (dusty) plasmas'.

2:12PM JO7.00002 Self-diffusion and random motion in a strongly-coupled dusty-plasma: experiment[1] , BIN LIU, J. GOREE, Dept. of Physics & Astronomy, The Univ. of Iowa — Self-diffusion and random motion in a two-dimensional (2D) dusty plasma were experimentally measured. A single-layer suspension of microsphere particles was levitated in an rf plasma, forming a strongly-coupled dusty plasma with a Yukawa interparticle potential. A pair of cw laser beams moves around the suspension and exerts radiation pressure forces on particles, providing an external control on particle temperature. A dusty-plasma solid is heated to form a dusty-plasma liquid. Particles are imaged, yielding an accurate measurement of particle position and velocity. Random motion is characterized by mean-square displacement (MSD), yielding an estimate of a diffusion coefficient, D. Dependence of D on temperature T is dominated by a power law at high T and an Arrhenius form at low T. Particle random motion obeys Gaussian statistics at high T, but not at low T as indicated by a probability distribution function (PDF) that resembles a kappa distribution. The PDF is self-similar for times longer than the ballistic time scale.

[1]Supported by DOE and NASA

2:24PM JO7.00003 Self-diffusion and random motion in a strongly-coupled dusty-plasma: MD simulation[1] , JOHN GOREE, BIN LIU, Dept. of Physics & Astronomy, The Univ. of Iowa, ZOLTAN DONKÓ, PETER HARTMANN, Research Institute for Solid State Physics and Optics of the Hungarian Academy of Sciences, Budapest, Hungary — A dusty plasma as in the accompanying talk by Liu and Goree is modeled as a 2D Yukawa system, with particles that are constrained to move on a plane and interact with a potential $U(r) = Q\exp(-r/\lambda_{\rm D})/r$, where Q is particle charge and $\lambda_{\rm D}$ is a screening length. We performed two independent molecular dynamics (MD) simulations that are frictionless and under equilibrium conditions, unlike the experiment, which is nonequilibrium driven-dissipative and anisotropic. As in the experiment, we tested the long-time behavior of MSD and VACF. We tested the choice of system size and thermostat on the characterization of diffusion. We compare the simulation MSD to the experiment, finding a match in the ballistic limit, but not in the diffusion limit. The MSD is much more superdiffusive in the simulation than in the experiment. For both the simulation and experiment, motion obeys Gaussian statistics at high T, but not at low T.

[1]Work was supported in the US by DOE and NASA and in Hungary by OTKA.

2:36PM JO7.00004 Laser manipulation of dust particles in Coulomb balls[1] , TIM FLANAGAN, J. GOREE, Dept. of Physics & Astronomy, The Univ. of Iowa — A dusty plasma is a partially ionized gas that contains small particles of solid matter, or dust. Dust particles become charged by collecting electrons and ions from the plasma, which can cause them to interact with a large potential energy in comparison with their thermal energy. This strong coupling causes dust particles to arrange themselves as a solid or liquid. One type of dusty plasma is the recently discovered Coulomb ball (Arp *et al.*, PRL 2004), which is a 3D spherically shaped suspension of dust. The ball becomes trapped due to a balance of three forces: the electric force due to the plasma electric field and a thermophoretic force resulting from a temperature gradient in the gas, which are both directed upward, and gravity. In this experiment, a glow-discharge plasma is used to confine $4.8\ \mu\text{m}$ microspheres forming a Coulomb ball inside a glass box atop a heated electrode. We report experimental results where radiation pressure, from one or more laser beams, is used to push some of the dust particles, creating a flow and reshaping the Coulomb ball.

[1]Supported by DOE and NASA

2:48PM JO7.00005 Heat transport in a two-dimensional complex (dusty) plasma at melting conditions[1] , V. NOSENKO, A.V. IVLEV, S. ZHDANOV, G. MORFILL, Max-Planck-Institute for Extraterrestrial Physics, J. GOREE, Dept. of Physics & Astronomy, Univ. of Iowa, A. PIEL, Christian-Albrechts University, Kiel, Germany — The heat transport in a two-dimensional complex (dusty) plasma undergoing a phase transition was studied experimentally. A single layer of highly charged polymer microspheres was suspended in a plasma sheath. In the absence of manipulation, the suspension forms a 2D triangular lattice. To melt this lattice and form a liquid, we used a laser-heating method. Two focused laser beams were moved rapidly around in the monolayer. The kinetic temperature of the particles increased with the laser power applied, and above a threshold a melting transition occurred. We used video microscopy for direct imaging and particle tracking. The spatial profiles of the particle kinetic temperature were calculated. Using the heat transport equation with an additional term to account for the energy dissipation due to the gas drag, we analyzed the temperature profiles to find a thermal conductivity, which did not depend on temperature.

[1]Work in Iowa supported by DOE and NASA.

3:00PM JO7.00006 Investigation of dust vertical dispersion relations , JIE KONG, KE QIAO, TRUELL HYDE, CASPER - Baylor University — The dust acoustic wave (DAW) was first theoretically predicted in 1990 by Rao et al. [Ref] and later observed experimentally by Barkan, et al. [Ref. 2], Pieper and Goree [Ref. 3] and others. The charge on the dust, Debye length and various other fundamental complex plasma parameters can be obtained experimentally through measurement of the DAW. Since under normal laboratory conditions, ordered structures formed within a complex plasma are generally two dimensional in nature, the majority of experiments to date examining such a system's dispersion relationships have been conducted on the horizontal plane. We will present an experimental method providing for a vertical dispersion relationship measurement, and present corresponding data. References [1]. N. N. Rao, P. K. Shukla, and M. Y. Yu, "Dust-acoustic waves in dusty plasmas," Planet. Space Sci. 38, 543-546 (1990). [2]. A. Barkan, R. L. Merlino, and N. D'Angelo, "Laboratory observation of the dust-acoustic wave mode," Phys. Plasmas, 2, 3563-3565, 1995. [3]. J. B. Pieper, J. Goree, "Dispersion of Plasma Dust Acoustic Waves in the Strong-Coupling Regime," Phys. Rev. Lett., 77, 3137-3140, 1996.

3:12PM JO7.00007 Determination of Plasma Sheath and Dust Parameters from Dust Particle Oscillation Modes , KE QIAO, JORGE CARMONA-REYES, BERNARD SMITH, MIKE COOK, JIMMY SCHMOKE, TRUELL HYDE, CASPER - Baylor University — The fundamental parameters of a complex dusty plasma system, including particle charge and dust Debye length, can be determined from the thermally excited oscillation modes of an arbitrary number of dust particles (either a dust cluster or plasma crystal) confined on a 2D plane within the plasma sheath produced above the lower electrode of a GEC reference cell [Ref. 1-2]. This paper will discuss an experimental technique allowing the strength of the confining potential well on the horizontal direction to be determined in the same manner. This technique will be further applied to systems of dust grains comprised of both melamine formaldehyde and ferromagnetic monodisperse particles.

3:24PM JO7.00008 Effect of Dipole-Dipole Charge Interactions on the Coagulation of Fractal Aggregates , LORIN MATTHEWS, TRUELL HYDE, CASPER - Baylor University — The coagulation of charged aggregates consisting of micron-sized dust grains is an important process in fields as diverse as planet formation and plasma processing of silicon wafers for computer chips. The coagulation rate is of particular interest in the plasma and radiative environment of a protoplanetary disk around a newly formed star, as recent evidence suggests that planet formation is very efficient and takes place on a relatively short time scale. Although it would seem intuitively obvious that like-charged grains would repel each other and reduce coagulation rates, the distribution of charge over the fractal structure of the aggregates can play a role in increasing the coagulation rate. In this study, we use a self-consistent N-body code to model the dipole-dipole interactions of charged aggregates during the coagulation process. The charge on the aggregates (monopole and dipole moments) is calculated using a heuristic scheme based on a detailed charging model for fractal aggregates using a modified orbital-motion limited theory.

3:36PM JO7.00009 Modeling of small dust Coulomb crystals in PECVD reactors[1] , MOHAMMAD DAVOUDABADI, BENIAMINO ROVAGNATI, FARZAD MASHAYEK, University of Illinois at Chicago — Modeling of dust crystal structures in the confining potential wells of laboratory non-equilibrium plasmas is of value from both aspects of theory and application. Motivated by simulation of process of nano-particle coating via Plasma Enhanced Chemical Vapor Deposition (PECVD) technique, whose underlying physics coincides with the dust contamination in PECVD reactors of microelectronics industry, we first simulate the plasma phase in a cylindrical PECVD reactor employing the local-field drift-diffusion model. Using a Lagrangian approach, we then three-dimensionally track a few number of interacting particles in a one-way coupling manner. After the particles reach their equilibrium state, their various multi-shell configurations are directly compared to the pertinent experiments. Meanwhile, a particle along with the ion focusing effect due to the ion flow in the sheath region is modeled as a superposition of the uncompensated residual plasma-shielded monopole, plus a plasma-shielded electric dipole. It is shown that the proposed model can successfully predict the vertically-aligned morphology of multi-layer arrangements of particles.

[1]This work was conducted under NSF grant CBET-0651362.

3:48PM JO7.00010 PIC-MCC study of particle charging in a collisional flowing plasma[1] , BENIAMINO ROVAGNATI, MOHAMMAD DAVOUDABADI, University of Illinois at Chicago, GIOVANNI LAPENTA, Katholieke Universiteit Leuven, Celestijnenlaan, Belgium, and Los Alamos National Laboratory, FARZAD MASHAYEK, University of Illinois at Chicago — In the framework of both dusty plasmas and material processing technologies for nanoparticles such as Plasma Enhanced Chemical Vapor Deposition (PECVD), the charging process of a single grain is one of the most important and most studied phenomena. It determines the particle interactions with plasma electrons and ions, with electromagnetic fields, between the particles themselves, and strongly relates to the particle coating growth rate in PECVD processes. In the present study, we model the charging phenomenon of a single particle which is immersed in a collisional flowing plasma via Particle-In-Cell (PIC) method. Both ions and electrons are fully tracked as computational particles and collisional charge-exchange process is accounted for by use of the Collisional Monte Carlo (MCC) approach. We consider a particle radius of the order of the electron Debye length. Particle potential, plasma species distributions and ion drag force are calculated under different operating conditions, such as plasma density and plasma drift velocities.

[1]This work was conducted uner NSF grant CBET-0651362.

4:00PM JO7.00011 Density profile and breathing mode of strongly correlated spherical Yukawa plasmas[1] , CHRISTIAN HENNING, ITAP, University of Kiel, KENJI FUJIOKA, City College of New York, PATRICK LUDWIG, MICHAEL BONITZ, ITAP, University of Kiel — The structure of "Yukawa balls," i.e. spherical 3D dust crystals, which recently have been produced [1], is well explained by computer simulations of charged Yukawa interacting particles within an external parabolic confinement [2]. Dynamical properties (e.g. breathing mode) of these systems were investigated by experiment, simulations as well as theoretically by using the ansatz of a uniform ground state density [3]. Here we show analytically that screening has a dramatic effect on the density profile which decreases away from the center [4,5] and which is in excellent agreement with MD simulations of Yukawa balls. This result is used to improve former calculations of the breathing mode [6].

References

[1] O. Arp et al. Phys. Rev. Lett. 93, 165004 (2004)
[2] M. Bonitz et al., Phys. Rev. Lett. 96, 075001 (2006)
[3] T. E. Sheridan, Phys. Plasmas 13, 022106 (2006)
[4] C. Henning et al., Phys. Rev. E 74, 056403 (2006)
[5] C. Henning at al., Phys. Rev. E (2007)
[6] C. Henning at al., submitted for publication

[1] Supported by the DFG (via SFB-TR24) and the DAAD RISE Program

4:12PM JO7.00012 Nonlinear Structures in Very Dense Plasmas , PADMA KANT SHUKLA, Theoretical Physics IV, Ruhr-University Bochum, D-44780, Bochum, Germany, BENGT ELIASSON, Theoretical Physics IV, Ruhr-University Bochum, D-44780 Bochum, Germany — We present numerical studies of the formation and dynamics of dark solitons and vortices in very dense quantum electron plasmas. The electron dynamics in the latter is governed by a pair of equations comprising the nonlinear Schrödinger and Poisson system of equations, which conserves the number of electrons as well as their momentum and energy. The present governing equations in one spatial dimension admit stationary solutions in the form a dark envelope soliton. The dynamics of the latter reveals its robustness. Furthermore, we numerically demonstrate the existence of cylindrically symmetric two-dimensional quantum electron vortices, which survive during collisions by forming vortex pairs. The nonlinear structures presented here may serve the purpose of transporting information at quantum scales in ultracold micromechanical systems and dense plasmas, such as those created during intense laser-matter interactions.

4:24PM JO7.00013 The Relativistic Feedback Mechanism of Electrical Breakdown. , HAMID RASSOUL, JOSEPH DWYER, Florida Institute of Technology — In 2003, a new electrical breakdown mechanism, referred to as Relativistic Feedback, was introduced. Relativistic Feedback involves the production of runaway electron avalanches by positive feedback from runaway positrons and energetic photons and allows runaway discharges in gases to become self-sustaining, dramatically increasing the flux of runaway electrons, the accompanying high-energy radiation, and resulting ionization. Based upon detailed Monte Carlo calculations, properties of Relativistic Feedback are presented. It will be shown that once Relativistic Feedback commences, electrical breakdown will occur, and the ambient electric field, extending over cubic-kilometers, will be discharged in as little as 20 microseconds. Furthermore, the flux of energetic electrons and x-rays generated by this mechanism can exceed the flux generated by the standard relativistic runaway electron process by a factor of 10 trillion, making Relativistic Feedback a good candidate for explaining Terrestrial Gamma-ray Flashes and other high-energy phenomena observed in the Earth's atmosphere.

4:36PM JO7.00014 The role of thermal and runaway electrons in lightning initiation[1] , M. BAKHTIARI, J. R. DWYER, H.K. RASSOUL, Z. SALEH, Florida Institute of Technology — Relativistic runaway breakdown acting on extensive cosmic-ray air showers is one of the proposed mechanisms for solving the mystery of lightning initiation. In this mechanism an air shower creates an avalanche of runaway electrons in neutral air, leaving behind a weakly ionized plasma with a tiny population of thermal electrons. Some researchers have suggested that this weakly ionized plasma produces enough conductivity to develop a lightning leader. In this presentation, we revisit the dynamics of runaway electrons in electrified air, and we obtain a pitch angle scattering term in the single-particle trajectory in momentum- space. This term considerably changes the picture of the single-particle runaway electron trajectory in neutral gases, illustrating the importance of elastic scattering for runaway electron calculations. In addition, we have used a Monte Carlo simulation to investigate whether the number of thermal electrons generated during a runaway electron avalanche is enough to induce the necessary conductivity for developing the lightning leader.

[1] This work was supported by the NSF under Grant No. ATM 0133773.

4:48PM JO7.00015 Microwave Plasma Confinement and Alfven Wave Ion Heating , JUN-CHIEH WANG, JANG-YU HSU, Department of Physics and Plasma and Space Physics Center, NCKU, Tainan, Taiwan — An incident electromagnetic wave with its reflection from an opposite mirror forming a standing wave can easily be absorbed by electrons [1,2] through linear mode conversion into the Langmuir wave [3]. The collisionless electrons at more than 10KeV responding to the ac electric field could excite an ac current that pinches the plasma and results in a plasma equilibrium. Moreover, the oscillatory electric field may excite an Alfven wave. Since half of the Alfven wave energy is in the ion flow energy, the ion kinetic energy can thus be increased with randomization in the flow velocity. The theory is being developed to compare with the experimental details.

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[2] L. P. Grachev, I. I. Esakov, K. V. Khodataev , Technical Physics Vol. 48, No. 5, p.557, May 2003.
[3] Thomas H. Stix, Phys. Rev. Lett., 15, 878, 1965

2:00PM - 2:00PM –

Session JP8 Poster Session IV: Education and Outreach; Undergraduate Research; Electron and Ion Beam/Space Charge; DIII-D I; Reversed Field Pinches; Energetic Ions and Electrons in Helicons Rosen Centre Hotel Grand Ballroom, 2:00pm - 5:00pm

JP8.00001 EDUCATION AND OUTREACH –

JP8.00002 Plasma Physics/Fusion Energy Education at the Liberty Science Center , ANDREW ZWICKER, JOHN DELOOPER, ANDY CARPE, Princeton Plasma Physics Laboratory, JOE AMARA, NANCY BUTNICK, ELLEN LYNCH, JEFF OSOWSKI, Liberty Science Center — The Liberty Science Center (LSC) is the largest (300,000 sq. ft.) education resource in the New Jersey-New York City region. A major $109 million expansion and renewal was recently completed. Accordingly, PPPL has expanded the science education collaboration with the Center into three innovative, hands-on programs. On the main floor, a new fusion exhibit is one of the focuses of "Energy Quest." This includes a DC glow discharge tube with a permanent external magnet allowing visitors to manipulate the plasma while reading information on plasma creation and fusion energy. In the section of LSC dedicated to intensive science investigations (20,000 sq. ft) we have added "Live from NSTX" which will give students an opportunity to connect via video-conferencing to the NSTX control room during plasma operations. A prototype program was completed in May, 2007 with three high school physics classes and will be expanded when NSTX resumes operation. Finally, a plasma physics laboratory in this area will have a fully functioning, research-grade plasma source that will allow long-term visitors an opportunity to perform experiments in plasma processing, plasma spectroscopy, and dusty plasmas.

JP8.00003 Educational Outreach at CASPER , TRUELL HYDE, BERNARD SMITH, JORGE CARMONA-REYES, CASPER - Baylor University — The CASPER Educational Outreach program with support from the Department of Education, the Department of Labor and the National Science Foundation advances physics education through a variety of avenues including CASPER's REU / RET program, High School Scholars Program, spiral curriculum development program and the CASPER Physics Circus. These programs impact K-12 teachers and students providing teachers with curriculum, supporting hands-on material and support for introducing plasma and basic physical science into the classroom. The most visible of the CASPER outreach programs is the Physics Circus, created during the 1999-2000 school year and funded since that time through two large grants from the Department of Education. The Physics Circus is part of GEAR UP Waco (Gaining Early Awareness and Readiness for Undergraduate Programs) and was originally one of 185 grants awarded nationwide by the U. S. Department of Education in 1999 to help 200,000 disadvantaged children prepare for and gain a pathway to undergraduate programs. The CASPER Physics Circus is composed of intense science explorations, physics demonstrations, hands-on interactive displays, theatrical performances, and excellent teaching experiences. Examples and efficacy data from the above will be discussed.

JP8.00004 Plasma Science and Applications at the Intel International Science and Engineering Fair , LEE BERRY, Oak Ridge National Laboratory, COALITION FOR PLASMA SCIENCE TEAM — Three years ago, the Coalition for Plasma Science (CPS) established a plasma prize at the Intel International Science and Engineering Fair. The APS/DPP and the IEEE/PSAC have helped make this effort a success by helping to identify judges. Each year since then, the number of plasma-related projects has increased. This year's prize was awarded for an instrument that, based on the ratio of spectral emission in two bands, detects when a high-pressure street light is about to fail. This allows time for an, efficient, scheduled replacement rather that an emergency service call. The CPS is a broadly-based group of institutions and individuals whose goal is to increase the understanding of plasmas for non-technical audiences. CPS activities include maintaining a website, http://www.plasmacoalition.org, developing educational literature, organizing educational luncheon presentations for Members of Congress and their staffs, and responding to questions about plasmas that are received by the CPS e-mail or toll-free number. The science fair prize and other CPS activities depend on the voluntary labor of CPS members and associates. New participants are needed to expand CPS activities and reach a larger audience. Send an e-mail to the CPS at CPS@plasmacoalition.org for information.

JP8.00005 Effective Technology Integration Shows New Frontiers in Education , FRANCO PAOLETTI, East Windsor Regional School District, East Windsor, NJ , LISA MARIE CARLUCCI, Washington Township Public School District, Robbinsville, NJ — In this ever-changing world, technology is affecting how people view learning and the overall educational process. For an educator, the successful implementation of technology can be one of the most effective tools in the classroom. The introduction of virtual simulations of real life situations into what was once considered a teacher-centered classroom, allows the educator to meet the complex differentiated needs of a multi-faced student population. In this modified classroom, the focus naturally shifts on the students and their interaction with the rest of the class and beyond. Effective integration of technology literally opens a window onto the outside world providing students with increased motivation and with the necessary expertise to enter the workforce or successfully pursue higher education. This work analyzes the impact of technology, the methodologies currently in use, advantages and disadvantages, providing examples on how to successfully implement effective programs under budgetary constraints.

JP8.00006 UNDERGRADUATE RESEARCH —

JP8.00007 Measurement and Analysis of ECH Power Injected Into DIII-D[1] , P.S. JOHNSON, Butler U., J. LOHR, General Atomics — The 6 ECH waveguides at DIII-D are on the order of 100 meters in length with up to 16 miter bends. Accurate measurement of the ratio of generated-to-transmitted power gives the transmission line efficiency directly and is essential for analysis of experiments. The power generated by the gyrotrons is measured calorimetrically for each pulse, but direct measurements of the injected power have relied on analysis of modulated plasma heating, which can overlook significant power where plasma volumes are large and ECH driven temperature fluctuations are small. High power tests of efficiencies of individual components have been difficult due to mutual interaction of components, sensitivity of power monitors to polarization, and the generally high efficiency of the components. We report a direct measurement of the efficiencies of complete transmission lines, using a high power dummy load placed at the end of each DIII-D waveguide. Experimental results will be compared to previous measurements and to theoretical calculations of the performance of the components and waveguide lines.

[1]Supported by a US DOE National Undergraduate Fusion Fellowship and DE-FC02-04ER54698.

JP8.00008 Power Accounting in DIII-D[1] , M.J. MARTIN, Cornell U., J.G. WATKINS, SNL, C.J. MURPHY, T.E. EVANS, GA, M. JAKUBOWSKI, KFZ-Juelich, I. JOSEPH, UCSD, C.J. LASNIER, LLNL — The plasma facing components in a fusion reactor will be exposed to high levels of heat and particle flux. A full accounting of where the plasma energy is deposited is important for designing future fusion reactors. To understand where the power is going, we do a total power accounting in DIII-D for different conditions such as H-mode, ohmic, and ELM-free H-mode plasmas. We use measurements from IR cameras, bolometers, Langmuir probes, and thermocouples to determine the distribution and magnitude of power deposition inside the tokamak as well as the consistency of the different measurements. We compare the thermal response measurements with both a simple thermal diffusion model and a finite element thermal model of the target plate tiles. A basic parameter that relates heat and particle flux at the plasma/materials interface is the power transmission factor. By comparing the particle flux and heat flux, we can measure the sheath factor profile for each of the above conditions.

[1]Supported by the US DOE under DE-FC02-04ER54758, DE-AC04-94AL85000, DE-FG02-04ER54758, and W-7405-ENG-48.

JP8.00009 UV Induced Motion of a Fluorescent Dust Cloud in a DC Glow Discharge Plasma , MICHAEL HVASTA, The College of New Jersey, ANDREW ZWICKER, Princeton Plasma Physics Lab, PPPL / SULI TEAM — Understanding dust dynamics is a key concern for both processing and astrophysical plasmas. To this end, an experiment was designed where a silica ($<$5 μm) and fluorescent dust mixture was added to an argon DC glow discharge plasma. The fluorescent dust allows one to observe the entire 3D structure of the cloud when it is illuminated by a 100 watt UV ($\lambda = 365$ nm) lamp. This method offers an advantage over laser scattering techniques that only allow 2D slices of the cloud to be observed and is simpler than scanning mirror techniques or PIV (Particle Image Velocimetry). Under typical parameters (P=150 mTorr, V_{anode}= 100 V, $V_{cathode}$= 400 V, I_{total} =<2mA) when the cloud is exposed to the UV, the mixture fluoresces, moves $\sim$2mm towards the light source and begins rotating. Particle rotational velocities in excess of 3 $^{mm}/_{s}$ have been observed near the cloud's periphery while particle velocities decrease towards the center of the cloud. Both cloud translation and rotational velocity were found to be a function of UV intensity. Theoretical and experimental results will be presented.

JP8.00010 ECR Plasma Deposition of Copper , KELLY GREENLAND, Lock Haven University of Pennsylvania, ANDREW ZWICKER, Princeton Plasma Physics Laboratory — ECR plasma is used in processing due to its ability to produce stronger, denser, and more uniform plasma as opposed to other processing plasmas. Having a more controlled plasma makes it easier to prevent unintentional damage to the sample, by having fewer stray ions come in from undesired angles. Samples were sputtered on silicon wafers at various pressures, powers, and sample distances from the plasma, and then analyzed with a scanning electron microscope to determine the thickness, uniformity and contamination. A typical plasma's parameters would have a microwave power of 2500watts, a target bias of 125volts, and an argon pressure of 0.46mtorr. An optical spectrometer was utilized to measure impurity content within the chamber. In addition, two-line spectroscopy was performed to measure electron temperature in lieu of a Langmuir probe. These initial measurements allow one to undertake more advanced projects on this apparatus, as well as refine the measurements of electron temperature through additional resources or statistical calculations and acquire more precise values with less uncertainty by acquiring apparatus that is able to be more finely calibrated.

JP8.00011 Construction of a Plasma Dynamo Prototype , ANDREW SELTZMAN[1], Georgia Institute of Technology, CARY FOREST, ROCH KENDRICK, CAMI COLLINS, University of Wisconsin-Madison — A new plasma experiment to investigate the self-generation of magnetic fields has been proposed. Here, a prototype experiment is described which plans to verify the concept of inducing the rotation of a nearly magnetic field free plasma (confined at the boundary by a highly localized multicusp magnetic field). The experiment consists of a cylindrical vacuum chamber with a series of insulated permanent magnet rings in a cusp geometry (poles facing inward with alternating polarity along the walls and end caps of the cylinder). The resulting field is axisymmetric and decays quickly away from the walls. Metal electrodes positioned between the magnet rings are biased such that the resulting electric field induces plasma rotation through the ExB drift. The principle is quite general and by controlling the poloidal profile of the toroidal rotation, high magnetic Reynolds number plasmas flows can be generated that result in magnetic field self-generation or plasma flows unstable to the magnetorotational instabilty.

[1]National Undergraduate Fellowship

JP8.00012 $H\alpha$ power loss in SSPX , T.L. STEWART, C.A. ROMERO-TALAMAS, H.S. MCLEAN, D.L. CORRELL, Lawrence Livermore National Laboratory, Livermore, CA 94550, SSPX TEAM — An absolute calibration has been performed on each of the seven chords of the $H\alpha$ diagnostic [Z. Wang, G.A. Wurden, C.W Barnes, et al., Rev. Sci. Instrum. 72, 1059 (2001)] at SSPX. Simple models are used to estimate the total power lost to $H\alpha$ radiation throughout experimental shots. Using these models, high energy shots (Te $>$ 500 eV) are compared to low energy shots.

JP8.00013 Electrostatic dust detector with improved sensitivity[1] , D.P. BOYLE, Columbia University, C.H. SKINNER, A.L. ROQUEMORE, Princeton Plasma Physics Laboratory — Measurement of dust inventories in next-step fusion devices will be necessary to ensure compliance with safety regulations. A device for detection of dust on remote surfaces, consisting of an ultrafine grid of interlocking copper traces biased to 30-50V, has been developed and tested[1]. Impinging dust particles produce temporary short circuits and the resulting current pulses are recorded using nuclear counting electronics. A digital oscilloscope was used to analyze the current pulse waveform under various experimental conditions in order to enhance the sensitivity of the device. Preliminary results indicate an order of magnitude increase in sensitivity to carbon dust particles is possible. This would enable the detector to measure the low levels of dust ($\sim$5 ng/cm^2/shot) produced in NSTX. Results will be presented from both small 12x12 mm and large 50x50 mm detectors, using both carbon and tungsten dust. [1] C.V. Parker et al., J. Nucl. Mater., 363-365 (2007) 1461.

[1]Title note: Support is provided by the U.S. DOE Contract No. DE-AC02-76CH03073 and the 2007 National Undergraduate Fellowship Program in Plasma Physics and Fusion Energy Sciences

JP8.00014 Multi-element Magnetic "B-dot" Probe[1] , SAMUEL HARROLD[2], Univ Rochester, NUF, TOM INTRATOR, XUAN SUN, LANL — We describe a 24-element magnetic probe consisting of miniature commercial chip inductors that will be used to investigate the evolution of the magnetic field lines during a reconnection event. Eight clusters of three mutually orthogonal inductor coils mounted in a linear array provide *dB/dt* data in the x, y, and z directions with a spatial resolution of 0.5 cm. The probe will be part of the Reconnection Scaling Experiment (RSX) at Los Alamos National Laboratory, which creates multiple magnetic flux ropes of H^+ plasma. Using numerical integration, we expect to measure magnetic field strengths of 1-10 gauss. The plasma columns of RSX that undergo magnetic reconnection, merging, and bouncing evolve on a characteristic timescale of 1-10 μs, which is well within the probe's expected time resolution.

[1]This work was supported by the National Undergraduate Fellowship (NUF) through PPPL.
[2]Undergraduate Poster Session

JP8.00015 Structural Properties of Yukawa Tubes[1] , K. TIERNEY, Boston College, H. BAUMGARTNER, C. HENNING, M. BONITZ, Universitaet zu Kiel — Due to the highly charged dust particles, complex plasma systems become strongly correlated and often arrange in interesting structures [1]. Direct measurements of plasma parameters are difficult [2], but simulations have been proven to work as a diagnostic tool for the plasma crystals being studied. Here, we investigate a one component Yukawa plasma limited in radial movement by a confining potential but unrestricted in the lateral direction. We performed extensive Monte Carlo simulations for different densities in a system with periodic boundary conditions and compared the results with an analytic theory. The dust particles are found to arrange in particularly interesting structures, which can be compared to 2D plasma crystals [3] in the radial direction, but unique in the chains created laterally which were found to be dependent on the density, the screening parameter in the Yukawa interaction, and the temperature.
[1] O. Arp et al., Phys. Rev.Lett. 93, 165004 (2004)
[2] M. Bonitz et al. Phys.Rev. Lett. 96, 075001 (2006)
[3] V.M. Bedanov et al., Phys. Rev. B 49, 2667 (1994)

[1]Support by DFG (via SFB-TR24) and DAAD-Rise Program.

JP8.00016 Rotation Generation in Helicon Plasmas , BRANDON FETROE, Walla Walla University, JENNA KEFELI, Stuyvesant High School, HANTAO JI, Princeton Plasma Physics Laboratory, JILL FOLEY, Nova Photonics, YEVGENY RAITSES, Princeton Plasma Physics Laboratory — Angular momentum transport in accretion discs occurs significantly faster than predicted by classical viscosity. Magnetorotational instability (MRI) is proposed to generate the required turbulence necessary to enhance angular momentum transport. However, the physics of MRI is studied mostly by theory and simulation. Recently, study of MRI is beginning using liquid metal. In order to study MRI in plasmas, controlled rotation must first be generated. Radial DC current is a means for generating jxB torque when an axial magnetic field is applied. To accomplish this initial goal, two concentric cylindrical electrodes were designed, built, and will be inserted into helicon plasma. The radial profiles of both velocity and electron density will be obtained by Mach and Langmuir probes, and if available, initial results will be reported on the search for MRI.

JP8.00017 Validating the simulation of the effects of secondary neutrals on the MSE gas-filled-torus calibration[1] , WILLIAM SCHUMAKER, Lawrence Technological University, HOWARD YUH, FRED LEVINTON, Nova Photonics, Inc., STEVE SCOTT, Princeton Plasma Physics Laboratory — A common procedure of injecting a neutral beam into a gas-filled torus with known magnetic fields in vacuum is used to calibrate motional Stark effect (MSE) diagnostics on many toroidal magnetic devices. A cause of anomalies encountered in this calibration has been explained as a consequence of secondary neutrals from the ionized beam. Under certain conditions, these re-neutrals emit H-alpha spectra that have the proper Doppler shift to pass through the MSE filters yet have a different polarization than those from the primary beam neutrals, thus contaminating the measured Stark electric field angle. Existing IDL code has been adapted to simulate the gas-filled-torus calibration of MSE in Alcator C-Mod, NSTX, and TFTR vessel geometries. A sensitivity study involving the post-processing of outputs with different gas pressures, beam injection angles, magnetic field pitch angles, and system resolutions will benchmark the code against the respective experimental data.

[1]Research funded by USDOE DE-AC02-76CH03073.

JP8.00018 Soft X-ray Tomography at DIII-D[1] , H. RINDERKNECHT, Princton U., R.K. FISHER, General Atomics, E.M. HOLLMANN, UCSD, M.J. LANCTOT, Columbia U., F. VOLPE, ORAU — Two new 32 channel SXR pinhole cameras have been recently installed in the DIII-D tokamak. They are sensitive to photons in the 2-20 keV range, but an interchangeable set of diamond filters with five settings allows selection of the range of energies of interest. New tomographic inverters were developed and validated against analytic models and magnetically reconstructed EFIT equilibria. Tomographic inversion techniques suitable for use with the new diagnostic geometry and preliminary inversions of new SXR data will be presented, along with re-analysis of earlier measurements of disruption-generated fast electrons and equilibria. Thanks to a temporal resolution of a few microseconds, progress has also been made in the tomographic reconstruction of rapidly moving, relatively weak emitters such as rotating islands.

[1]Supported by the US DOE under a National Undergraduate Fusion Fellowship Program, DE-FC02-04ER54698, DE-FG02-04ER54758, and DE-FG02-89ER53297.

JP8.00019 Advanced Diagnostic Design for Paul Trap Simulator Experiment (PTSX)[1] , A.B. GODBEHERE, Cornell University, M. CHUNG, R.C. DAVIDSON, E.P. GILSON, Princeton Plasma Physics Laboratory — The Paul Trap Simulator Experiment (PTSX) is a compact laboratory Paul trap that uses a pure-ion plasma to simulate a long, thin charged particle bunch coasting through a kilometers-long magnetic alternating-gradient transport system. Current PTSX experiments are exploring the limits of the smooth focusing model, and using the detection of collective mode oscillations to infer key bunch properties such as the line density and transverse temperature. These experiments require the use of advanced diagnostics to measure the transverse distribution of the plasma perticles at a given instant in time. One set of experimental diagnostics uses a CCD camera with a short exposure time to collect light from Laser Induced Fluorescence (LIF) of the cross section of a barium plasma beam. A second set of experimental diagnostics utilizes capacitive coupling of the ions with four electrodes, which are connected to high- input-impedance active filters. Details of the design and performance of the laser system, CCD camera system, and collective mode diagnostic electronics will be presented.

[1]This research was supported by the U. S. Department of Energy and the National Undergraduate Fellowship Program.

JP8.00020 Retarding Field Energy Analyzer Measurements of Ion Velocity Distributions in a Helicon Plasma Source[1] , ZANE W. HARVEY, EARL SCIME, ROB HARDIN, ALEX HANSEN, WILLIAM PRZYBYSZ, West Virginia University — A four grid retarding field energy analyzer (RFEA), with a fifth grounded entrance grid, has been constructed based on published design criteria [Charles et al., Phys. Plasmas **7**, 5232 (2000).]. A fast amplifier is used to sum the current collected by the suppressor grid and the collector current. Measurements of the ion velocity distribution function (ivdf) as a function of neutral pressure and magnetic field mirror ratio in the HELIX plasma source will be presented. The ivdf measurements will also be compared to laser induced fluorescence measurements made at the same location in the expansion region of the plasma source.

[1]2007 Summer Undergraduate Research Experience at West Virginia University

JP8.00021 Development of a diagnostic array for the measurement of velocity profiles across open-channel liquid metal flows , ALEXANDER GILL, Colby College, MARK NORNBERG, HANTAO JI, JAYSON LUC PETERSON, PPPL — An array of potential probes utilizing the Hall effect to measure liquid metal flow velocity is developed and implemented in the Liquid Metal Experiment (LMX) at PPPL, a study of magnetohydrodynamic (MHD) stability in open-channel flow. The channel experiment has applications in the study of the dynamics of "plasma oceans" on the surface of neutron stars. Furthermore, liquid metal is studied as a possible material for plasma-facing components in fusion reactors, an avenue of research requiring an understanding of turbulent liquid metal flow under the influence of magnetic fields. Liquid gallium alloy circulates with a flow height of 1 cm through the open channel of dimensions 15 cm wide by 70 cm long within a uniform perpendicular magnetic field of strength up to 0.7 T. A series of 16 electrode pairs, one per centimeter from wall to wall across the width of the channel, detect potential differences across 2 mm sections of flow normal to the mean velocity and the magnetic field. For flow speeds of 0.2 m/s and magnetic field strengths of 0.1 T, a raw signal of about 40 μV is expected, which will be amplified with a gain of 1000. Velocity profiles will be measured at various heights in the flow. Design considerations, calibration procedures and results will be presented.

JP8.00022 Correlative data studies in NSTX: Studies of magnetic topology with the motional Stark effect diagnostic , DAVID NEWBY JR., Drew University, ELIZABETH FOLEY, Nova Photonics, Inc, FRED LEVINTON, Nova Photonics, Inc. — The motional Stark effect diagnostic has been implemented to measure the magnetic field pitch angle in the National Spherical Torus Experiment (NSTX). By measuring the polarization of H-alpha emission from the system's neutral beam injectors, it is possible to gather time-resolved data and observe the evolution of the pitch angle over the duration of a plasma discharge. This data facilitates inquiry into magnetic topology changes, including reconnection events that may be occurring. Understanding magnetic reconnection is vital to eventually achieving a stable burning plasma, as well as being of interest in space and astrophysical phenomena. Here, IDL is used to correlate data from the pitch angle and other diagnostics to gain insight into instabilities and reconnection events that occur within NSTX. Such insights are presented with illustrative examples of data.

JP8.00023 High Harmonic Fast Wave Propagation and Heating on NSTX[1] , J.B. PARKER, Cornell University, C.K. PHILLIPS, J.C. HOSEA, E.J. VALEO, J.R. WILSON, NSTX Team, Princeton Plasma Physics Laboratory, R.W. HARVEY, CompX — Recent experiments on the National Spherical Torus Experiment (NSTX) show that the high harmonic fast wave (HHFW) core heating efficiency depends on the antenna phasing and plasma conditions. [1]. Power losses in the edge due to rf sheath formation or other parasitic absorption processes could occur if the waves propagate nearly parallel to the wall in the edge regions and intersect nearby vessel structures. To investigate this possibility, the 3D HHFW propagation in NSTX has been studied both analytically and numerically with the ray tracing code GENRAY. Initial calculations show that for certain values of the launched parallel wave number and magnetic field, the waves in NSTX are launched at a shallow angle to the vessel wall. In contrast, for ICRF heating in C-Mod or ITER, the initial ray trajectories tend to be more radially oriented. Comparisons of the GENRAY results with 2D TORIC full wave simulations for the power deposition will also be discussed.
[1] See invited talk by J. C. Hosea this meeting.

[1]Work supported by USDOE DE-AC02-76CH03073.

JP8.00024 Modeling of Neutral Beam Ion Prompt Loss from NSTX Plasmas[1] , R.C. NORA, Colorado School of Mines, D.S. DARROW, Princeton Plasma Physics Laboratory — Neutral beam injection is a frequently used and effective means of heating magnetically confined fusion plasmas. While most of the injected neutrals are ionized and captured within the plasma, a fraction can be lost immediately to the wall due to being born on unconfined orbits, termed prompt loss. To minimize the computation time of calculating these prompt loss ions, the neutral beam ion phase space is reduced to two dimensions by coupling a simple beam deposition model with a constants of motion (COM) approach. In particular, we work with the magnetic moment and the canonical toroidal angular momentum. This approach allows easy visualization of the fast ion population in phase space and rapid calculation and display of the boundary between confined and lost particles. Since NSTX is equipped with a scintillator type fast loss ion probe, we are also evaluating whether this method can be used to predict the pitch angle profile of the prompt loss signal in the probe. In principle, this representation of the particle phase space might also be useful for simulation of other fast ion diagnostic signals. Example calculations and status of this work will be presented.

[1]This work performed under US DoE contract DE-AC02-76-CH03073.

JP8.00025 Calculation of Divertor Thermal Response as a Function of Material Composition for NSTX[1] , MICHAEL CHAFFIN, Reed College, RAJESH MAINGI, Oak Ridge National Laboratory — Present tokamak designs use a magnetic divertor to deposit heat from the edge plasma onto Plasma Facing Components (PFCs) designed to remove the heat. Studying how this heat is distributed under various discharge conditions gives insight into how heat deposition can be optimized, and how different materials respond to plasma heating. In the National Spherical Torus eXperiment (NSTX), infrared cameras are used to measure divertor surface temperature, from which heat flux is computed using a 1D semi-infinite slab model with constant thermal conductivity. Here, a 1D simulation of the PFCs incorporating temperature-dependent thermal properties is used to compute heat flux profiles resolved across time and tile thickness. The PFC response to a given heat flux is also computed, and comparisons of resulting temperature profiles are made for a variety of materials including ATJ graphite (presently in the NSTX divertor), pyrolytic graphite, molybdenum, and tungsten.

[1]Research sponsored in part by Student Undergraduate Laboratory Internships, administered by Princeton Plasma Physics Laboratory, and US DOE contract DE-ACO5-00OR22725.

JP8.00026 Plasma Sheath and RF Wave Interaction in Tokamaks , DANIEL RICHMAN[1], University of Rochester, JOHN WRIGHT, MIT Plasma Science and Fusion Center — This project is part of recent efforts to theoretically and computationally model the radio frequency (RF) heating of tokamak plasmas. The antenna and containment vessel surface have important effects on the heating efficiency of the RF waves. Power loss in the sheath that forms at the edge of the plasma is a primary concern. The magnetic field topology at the vessel surface is important for nonlinear absorption mechanisms. We used archived data from the Alcator C-Mod tokamak at MIT, and prepared it through IDL and Fortran procedures to be used as a boundary condition at a simulated vessel wall in the TORIC code that simulates RF wave propagation in a tokamak. The code was run in an iterative fashion to address the nonlinearity of the situation and achieve a self-consistent solution for power deposition and sheath width, as described in [D. D'Ippolito and J. Myra, Phys. Plasmas 13, 102508 (2006)]. Conclusions could then be drawn regarding the locations of high power loss.

[1]Sponsored during summer 2007 at MIT PSFC by Dept. of Energy National Undergraduate Fellowship in Plasma Physics and Fusion Energy Sciences

JP8.00027 Calculation of charge-changing cross sections of ions or atoms colliding with fast ions using classical trajectory method , HARRISON EDWARD MEBANE, ARIEL SHNIDMAN, IGOR D. KAGANOVICH, RONALD C. DAVIDSON[1], Princeton Plasma Physics Laboratory — Evaluation of ion-atom charge-changing cross sections is needed for many accelerator applications. A classical trajectory Monte Carlo simulation has been used to calculate ionization and charge exchange cross sections. For benchmarking purposes, an extensive study has been performed for the simple case of hydrogen and helium targets in collisions with various ions. To improve computational efficiency, several integration methods, including Runge-Kutta with adaptive stepsize and Bulirsch-Stoer with Stoermer's Rule, were compared. Despite the fact that the simulation only accounts for classical mechanics, the calculations are comparable to experimental results for projectile velocities in the region corresponding to the vicinity of the maximum cross section.

[1]Research supported by the US Department of Energy.

JP8.00028 Extensions to DG, a Graphical Tool for Editing 2D Edge Plasma Quasi-Orthogonal Computational Meshes[1] , A.Y. CHIN, D.P. STOTLER, PPPL — DG is a tool used, in combination with mesh generating codes such as Carre and Sonnet, to create and modify "structured curvilinear quasi-orthogonal meshes"[2] for use in modeling plasma and neutral transport in the boundary of tokamak magnetic confinement experiments. DG has already been used to define the geometry used by the B2-Eirene code in simulating the neutral transport behavior in the ITER divertor[3]. Another recent application is DEGAS 2 modeling of Gas Puff Imaging experiments on the National Spherical Torus eXperiment[4]. We describe how we brought DG into compatibility with the freely available Open Motif 2.x library, allowing it to be run reliably on the LINUX cluster at PPPL. In addition, several new features added to DG are presented. Together, these improvements allow precisely tailored and general meshes to be generated more quickly and easily, accelerating the progress of computational studies on tokamak plasmas.

[1]This work supported by the DOE Science Undergraduate Laboratory Internships program and US DOE contract DE-AC02-76CH03073.
[2]R. Marchand and M. Dumberry, Comp. Phys. Comm. **96**, 232 (1996).
[3]A. S. Kukushkin et al., Nucl. Fusion **45**, 608 (2005).
[4]D. P. Stotler et al., J. Nucl. Mater. **363–365**, 686 (2007)

JP8.00029 Exact canonical drift Hamiltonian formalism with pressure anisotropy and finite perturbed fields , GUY A. COOPER, University of the South, Sewanee, TN 37383 and Ecole Polytechnique Federale de Lausanne CRPP, Association Euratom-Suisse, Lausanne, Switzerland, MARTIN JUCKER, W. ANTHONY COOPER, JONATHAN GRAVES, Ecole Polytechnique Federale de Lausanne CRPP, Association Euratom-Suisse, Lausanne, Switzerland, MAXIM ISAEV, Nuclear Fusion Institute, RRC Kurchatov Institute, Moscow, Russia — A Hamiltonian formulation of the guiding center drift orbits is extended to pressure anisotropy and field perturbations in axisymmetric systems. The Boozer magnetic coordinates are shown to retain canonical properties in anisotropic pressure plasmas with finite electrostatic perturbations and electromagnetic perturbed fields that affect solely the parallel component of the magnetic vector potential. The equations of motion developed in the Boozer coordinate frame are satisfied exactly by direct verification of the drifts.

JP8.00030 Tokamak Plasma Equilibrium Controllability Limitations Due to Delays[1] , D. SONDAK, E. SCHUSTER, Lehigh U., M.L. WALKER, General Atomics — When designing the control loops for tokamaks, it is important to acknowledge the effects of time delays. An assumption which is sometimes made is that if the system open loop response is intrinsically slow, due for example to substantial vessel shielding or to the imposition of limits on rate of change of control currents, then extra time delays which are individually shorter than these will not have significant undesirable effects on control. However, because delays and phase lags are in general cumulative in effect, this assumption is typically incorrect. This study examines and quantifies these effects in the axisymmetric control loop in superconducting tokamaks, for the case of plasma current control, radial and vertical position control, and plasma boundary control. Delays in the power supplies, data acquisition, and vessel structure are taken into account. Methods for remediating the negative effects due to time delays are also presented.

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), the NSF CAREER award program (ECCS-0645086), and the US DOE under DE-FG02-92ER54141, and DE-FC02-04ER54698.

JP8.00031 Effects of Magnetic Measurement Uncertainty and Non-axisymmetry on Tokamak Equilibrium Reconstruction[1] , D.P. FLANAGAN, D.P. BRENNAN, U. of Tulsa, L.L. LAO, E.J. STRAIT, GA, A.L. MONTGOMERY, U. Wisc.-Madison — Constraints must be imposed on the pressure and current profiles to solve the Grad-Shafranov equation during equilibrium reconstruction of tokamak plasmas. Rigorous consideration of magnetic measurement uncertainty is necessary to impose physically consistent constraints, yielding the best solution. Discharges from DIII-D are analyzed with two versions of EFIT. The first is the currently public version. The second utilizes a newly added magnetic uncertainty matrix based on detailed estimates of uncertainty in magnetic measurements of DIII-D expected to improve the accuracy of reconstruction and of estimates of error in reconstruction. Reconstructions using these methods are compared to determine the effects of the uncertainty matrix. Preliminary results indicate the new EFIT returns similar values for global plasma parameters such as β_p, l_i, and shape with a more realistic χ^2 than the public version. Furthermore, the effects of non-axisymmetry on reconstructions are explored.

[1]Supported by US DOE under a National Undergraduate Fusion Fellowship Program and DE-FC02-04ER54698.

JP8.00032 Magnetic Mapping Techniques for Poloidally Diverted Tokamaks[1] , M. RAMM, Stanford U., I. JOSEPH, UCSD, T.E. EVANS, General Atomics — Resonant magnetic perturbations have recently been used to control type-I ELM instabilities by controlling the edge pressure gradient of the DIII-D tokamak. To characterize the 3D structure of the perturbed magnetic field, we have developed an efficient symplectic mapping technique based on the Hamilton Jacobi method. We first numerically determine the resonant Hamiltonian of the magnetic field lines inside DIII-D. Then the Hamilton Jacobi method is used to construct a symplectic map describing the spatial structure of the magnetic field near the separatrix. We use this map to numerically compute a number of quantitative features of the tokamak. We determine the Lyapunov exponents, describing the divergence of the field lines inside the tokamak. We also study the fractal nature of the magnetic field near the divertor plates. The results are compared with other methods of numerical approximation as well as analytic techniques.

[1]Supported by the US DOE under a National Undergraduate Fusion Fellowship Program, DE-FG02-05ER54809 and DE-FC02-04ER54698.

JP8.00033 Computational Fluid Dynamics (CFD) simulation of the Madison Dynamo Experiment. , N.S. HAEHN, C.B. FOREST, C.R. WEBER, R.D. KENDRICK, N.Z. TAYLOR, J.G. OAKLEY, R. BONAZZA, University of Wisconsin - Madison, ERIK SPENCE, ETH-Zurich — The Madison Dynamo Experiment is designed to study a self-generated magnetic field called a dynamo. The flow characteristics of a water experiment that is dimensionally similar to the liquid sodium experiment has been modeled using the Computational Fluid Dynamics (CFD) software *Fluent*. Results from the CFD simulations are used to confirm flow characteristics measured experimentally by both Laser Doppler Velocimetry (LDV) and Particle Imaging Velocimetry (PIV). Simulations can also give insight into the flow characteristics in regions of the experiment which are not accessible via the LDV and PIV systems. The results from the simulations are also used as input for a MHD code to predict the threshold for Dynamo onset. The CFD simulations – in conjunction with the MHD dynamo prediction code – can be used to design modifications to the experiment to minimize costly changes. The CFD code has shown that the addition of an equatorial baffle along with several poloidal baffles can lower the threshold for Dynamo onset.

JP8.00034 MHD Mode Identification Using Magnetic Probes and Its Application to the Edge Harmonic Oscillation[1] , N.C. STONE, Cornell U., H. REIMERDES, Columbia U., E.J. STRAIT, K.H. BURRELL, GA — Magnetohydrodynamic instabilities in tokamak plasmas are usually known for their role in limiting plasma performance. However, the edge harmonic oscillation (EHO) seen in quiescent H-mode plasmas has advantageous effects because it increases edge particle transport, allowing control of the edge pressure. By operating with edge pressures stable to peeling-ballooning modes, edge localized modes (and their intense bursts of heat to the wall) can be avoided. This study aims to improve the understanding of the EHO through the creation of a filament-based toroidal current model capable of simulating both plasma and induced vessel currents. This model predicts the magnetic fields measured by Mirnov probes, serving as a synthetic diagnostic for the presence of MHD instabilities. After tests validate the model against 2/1 and 3/2 tearing modes, it will be used to localize the EHO. This will be accomplished with a least squares fit of simulated m/n modes to experimental observations of the EHO.

[1]Supported by US DOE under a National Undergraduate Fusion Fellowship Program, DE-FG0289ER53297 and DE-FC02-04ER54698.

JP8.00035 Linear and Nonlinear Studies of Trapped Electron Mode Turbulence[1] , M. HOFFMAN, Univ. Missouri - Rolla, D.R. ERNST, MIT — Linear stability diagrams are presented to clarify the onset of toroidal drift modes, including ITG, and resonant and non-resonant TEMs, as a function of density and temperature gradients. Several hundred linear gyrokinetic stability analysis were performed with the GS2 code[2] to generate a stability diagram, varying density and temperature gradients around the "Cyclone Base Case." Two separate studies have previously found that zonal flows play very different roles in TEM turbulence. The first,[3] found that zonal flows play a strong role near threshold, where they produce a nonlinear upshift. The second,[4] for a case well above threshold, found that zonal flows have little effect on the turbulent saturation level. To better understand this behavior, we are performing a series of nonlinear gyrokinetic simulations to analyze the anisotropy of the turbulent eddies, and the role of zonal flows, as a function of drive.

[1]Work supported in part by U.S. Dept. of Energy National Undergraduate Fellowship Program.
[2]W. D. Dorland *et al.*, Phys. Rev. Lett. 85 (2000) 5579.
[3]D. R. Ernst *et al.* Phys. Plasmas 11(5) (2004) 2637. Also IAEA-CN-149/TH/1-3 (2006).
[4]T. Dannert *et al.* Phys. Plasmas 12 (2005) 072309.

JP8.00036 Comparative Study to Determine an Optimal Material for Tritium Production in a Direct Drive IFE Reactor , MARIA ARISTOVA, CHARLES GENTILE, Princeton Plasma Physics Laboratory — An important technical and economic consideration in designing the prospective direct drive inertial fusion energy (IFE) reactor is the determination of a suitable mechanism for tritium breeding. A comprehensive review is undertaken to determine the optimal breeding material, examining two candidate compounds: 83Pb-17Li and $(LiF)_2BeF_2$ (FLiBe). In this study, the compounds are evaluated based on chemical and physical properties, structural requirements, feasibility, hazards, and costs of application. Preliminary results seemed to indicate that FLiBe may be the more practical option, due to its mechanical utility and the relative projected efficacy of blanket design. However, much remains to be investigated, particularly the properties of breeder and structural materials in the specific conditions of a reactor. This evaluation process will require further theoretical modeling as well as practical trial, currently planned in other progenitor reactor designs. This paper will present the results of the analysis of these candidate breeder materials.

JP8.00037 Conceptual Design for a 2 GW Inertial Fusion Energy (IFE) Direct-Drive Power Reactor Employing Magnetic Intervention[1] , K.R. TRESEMER, George Fox University, C.A. GENTILE, Princeton Plasma Physics Laboratory — Presented is a conceptual design for a 2 GW IFE direct drive fusion power reactor. This design employs a cusp field to deflect IFE-generated ions away from the dry first wall of the target chamber and into specifically designed ion dumps. The reactor operates at 5 Hz, consuming ∼450,000 tritium targets/day, injected at >100 m/s into the target chamber and uniformly illuminated by laser light, stimulating detonation. The resulting fusion energy is collected by equatorial ion dumps equipped with heat exchangers. The reactor will breed and recycle its own fuel through the use of breeder blankets and a fuel recovery system. To minimize target-particle interference, the chamber will be kept at <0.5 mTorr through the use of magnetically levitated turbomolecular pumps (TMPs) and corresponding backing pumps. Under investigation are the principles of magnetohydrodynamics (MHD) which may be applied to attenuate and harness the energy residing in the post detonation ion fields.

[1]Support for this research was provided by the U.S. Department of Energy's Science Undergraduate Laboratory Internship (SULI) Program.

JP8.00038 Concept to Employ Magnetohydrodynamic (MHD) Conversion in a 2 GW Direct Drive Inertial Fusion Energy (IFE) Power Reactor , BRETT ANDERSON, St. Olaf College, ALISON BURSTEIN, Wesleyan University, CHARLES GENTILE, Princeton Plasma Physics Laboratory — The conceptual design of a 2 GW direct drive IFE power reactor may provide an opportunity to directly harness the power in the post detonation ion fields. Conceptually, this can be accomplished by utilizing a magnetic cusp field to guide the ions into equatorial and polar ion dumps. The ion fields resulting from this magnetic intervention configuration pose a distinct challenge, as their intensity may have the potential to damage the ion dumps. One method of addressing this challenge is by employing MHD conversion to transform the internal energy of the fields directly into electrical energy, a process which would also reduce the fields' strength. In order to analyze the potential of MHD conversion in IFE, results of previous work in other applications are examined in the context of this project. Preliminary assessment reveals that MHD conversion is a promising solution to this issue, although a number of engineering and practical concerns will need to be addressed. This paper concentrates on the primary issues associated with MHD conversion. *Support for this research was provided by the U.S. Department of Energy's Science Undergraduate Laboratory Internship (SULI) Program.*

JP8.00039 Implementation of Au Transmission Photocathode for Laboratory Astrophysics Diagnostics Research[1] , MARIANO LOWENSTERN, R. PAUL DRAKE, ERIC HARDING, CHANNING HUNTINGTON, GURLOVLEEN RATHORE, ANTHONY VISCO, University of Michigan — The development of laser driven experiments with a focus on Inertial Confinement Fusion has allowed scientists to carry on studies in Astrophysical phenomena that were previously impossible to duplicate. A type of tool used for the diagnostics of this experiments is known as an X-ray framing camera. This device makes use of the X-rays produced by plasma during such experiments and converts them into electrons that are detected by a phosphor material. We have implemented a detached Au transmission photocathode (160 Angstroms thick) on a MCP and are evaluating it using a 1.5 keV Al K-alpha X-ray source. We will report the results of measurements to determine whether this improves the effective quantum efficiency of the X-ray detection system.

[1]This research was sponsored by the Naval Research Laboratory through contract NRL N00173-06-1-G906 and by NNSA through DOE Research Grant DE-FG52-04NA00064.

JP8.00040 Elemental Analysis of Carbon Disks using Proton Induced X-ray Emission[1] , MELISSA CUMMINGS, KELLY DONOVAN, STEPHEN PADALINO, Physics and Astronomy, State University of New York at Geneseo, VLADIMIR GLEBOV, T. CRAIG SANGSTER, Laboratory for Laser Energetics, University of Rochester — An experimental method for determining the ρR and $(\rho R)^2$ of high energy-density inertial confinement fusion targets has been developed, which involves measuring the yield of tertiary neutrons with energies higher than 20 MeV. Carbon activation is a suitable technique for this measurement due to its high energy neutron reaction threshold and the availability of ultra high-purity samples at a relatively low cost. The tertiary neutron yield is more than six orders of magnitude lower than the primary neutron yield, so ultra pure carbon samples that are free from any positron-emitting contaminants are essential to this diagnostic. The goal of this project was to use proton induced x-ray emission (PIXE) as a technique for determining trace amounts of contaminant elements in the carbon disks.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics.

JP8.00041 Measuring Positron Annihilation in NaI(Tl) Detectors as the Final Stage in a Carbon Diagnostic.[1] , MELISSA BRAATEN, CASSARAH BROWN, STEPHEN PADALINO, Physics and Astronomy, SUNY Geneseo, VLADIMIR GLEBOV, T. CRAIG SANGSTER, TIMOTHY DUFFY, LLE, University of Rochester — This study was performed to increase the detection efficiency of 511 keV annihilation radiation from decaying C-11 by indentifying and eliminating different forms of background radiation originating from the source and the ambient background in the gamma ray coincidence spectrum. Cu-64 was substituted for C-11 in this investigation since it could be easily made from Cu-63 via neutron capture using a PuBe neutron source. Using Cu-64, the effect of ambient background and source induced radiation in the NaI detectors was examined in three coincidence spectra. The spectra were generated by pairing the output signals of the three NaI(Tl) detectors and displaying them as two dimensional spectra. Different gamma ray background contributions to the coincidence spectrum were studied, including annihilation radiation from pair production in the detectors and the lead shielding. Detector geometries and source materials which modified the Compton scattering background were also investigated.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics

JP8.00042 VELoCiRaPTORS.[1] , J. LUNDGREN, B. ESHAM, S.J. PADALINO, SUNY at Geneseo, T.C. SANGSTER, V. GLEBOV, LLE, University of Rochester — The Venting and Exhausting of Low Level Air Contaminants in the Rapid Pneumatic Transport of Radioactive Samples (VELoCiRaPTORS) system is constructed to transport radioactive materials quickly and safely at the NIF. A radioactive sample will be placed inside a carrier that is transported via an airflow system produced by controlled differential pressure. Midway through the transportation process, the carrier will be stopped and vented by a powered exhaust blower which will remove radioactive gases within the transport carrier. A Geiger counter will monitor the activity of the exhaust gas to ensure that it is below acceptable levels. If the radiation level is sufficient, the carrier will pass through the remainder of the system, pneumatically braking at the counting station. The complete design will run manually or automatically with control software. Tests were performed using an inactive carrier to determine possible transportation problems. The system underwent many consecutive trials without failure. VELoCiRaPTORS is a prototype of a system that could be installed at both the Laboratory for Laser Energetics at the University of Rochester and the National Ignition Facility at LLNL.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics

JP8.00043 Noble Gas Analysis for the OMEGA Gas Sampling System[1] , G.T. YOUNG, S.M. HUPCHER, C.G. FREEMAN, Physics and Astronomy, SUNY Geneseo, M.A. STOYER, Lawrence Livermore National Laboratory, T.C. SANGSTER, LLE, University of Rochester — The OMEGA Gas Sampling System (OGSS) at the Laboratory for Laser Energetics can be used to study a wide variety of implosion parameters in inertial confinement fusion. By doping a target capsule with carefully chosen detector nuclei, nuclear reactions between fusion products and detector nuclei can produce noble gas isotopes. Following a capsule implosion, these gases are pumped out of the target chamber and are collected into sample bottles. We have developed a bench-top analysis station at Geneseo capable of determining the number of noble gas atoms present in the sample bottles. A needle valve is used to admit gas from the sample bottles into a vacuum chamber at a controlled rate. The conductance of the needle valve is a function of pressure and gas type. A residual gas analyzer (RGA) is used to measure the partial pressures of each type of noble gas in the vacuum chamber. The RGA is calibrated with a calibrated leak, which allows known amounts of different gases into the chamber at a constant rate. Analysis of the gasses collected following a D^3He implosion is currently underway.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics.

JP8.00044 Modeling a Carbon Diagnostic System Using MCNPX[1] , S.H. FAY, C.M. KUHN, E.E. SMITH, S.L. STEPHENSON, Gettysburg College, T.C. SANGSTER, V. GLEBOV, LLE University of Rochester, S.J. PADALINO, SUNY Geneseo — Monte-Carlo N-Particle Extended (MCNPX) is currently being used to model various carbon diagnostic configurations for use at OMEGA with plans to design a similar system for the NIF. The purpose of such models is to optimize the carbon diagnostic's detection of signature products (i.e. tertiary neutrons) from a self-sustaining inertial confinement fusion (ICF) implosion. Results will be presented.

[1]Funded in part with a grant from the United States Department of Energy.

JP8.00045 Impact of Cryogenic Temperatures on the Mechanical Properties of *Steatoda Triangulosa* Spider Silk[1] , EDWARD POGOZELSKI, BRENDAN SEE, CHRISTINA KIEFFER, WILLIAM BECKER, STEPHEN PADALINO, Physics and Astronomy, State University of New York at Geneseo, CRAIG SANGSTER, University of Rochester, Laboratory for Laser Energetics — The mechanical properties of dragline spider silk from the species *Steatoda Triangulosa* are examined at 77K. Dragline silk is used as a structural material to support deuterium - tritium laser fusion targets at the Laboratory for Laser Energetics (LLE) in Rochester, NY. As the targets are filled, the dragline is exposed to cryogenic temperatures. To simulate this environment, silk is dipped into liquid nitrogen. The strength, toughness, and modulus of elasticity of silk in liquid nitrogen are compared to these properties in air. Cryogenic dragline is 200% as strong, 125% as tough, and has an elastic modulus of 300% compared to silk in air at room temperature.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics

JP8.00046 Preparation of Deuterated Polymer Targets for the OMEGA Magnetic Recoil Spectrometer[1] , JACQUELINE STRAIN, GERALD RAWCLIFFE, JOSEPH KATZ, KURTIS FLETCHER, Physics and Astronomy, State University of New York at Geneseo, JOHAN FRENJE, Plasma Science and Fusion Center, Massachusetts Institute of Technology, SEAN MACMULLIN, Physics and Astronomy, University of North Carolina - Chapel Hill — Uniform deuterated polymer films on tantalum substrates are used as targets for the new Magnetic Recoil Spectrometer (MRS) at the OMEGA laser system at the University of Rochester's Laboratory for Laser Energetics. The MRS is designed to measure the neutron energy spectrum produced in inertial confinement fusion (ICF) experiments by detection of deuterons elastically scattered from the polymer target. The goal of our project is to produce circular films with areas ranging from 2 to 15 cm^2 and thicknesses ranging from 40 to 300 microns. Design parameters stipulate that the polymer thicknesses must be characterized to within 5% with less than 5% variation throughout the sample. Methods for preparing and characterizing these films will be discussed.

[1]Supported in part by the US Department of Energy through the Laboratory for Laser Energetics at the University of Rochester.

JP8.00047 Improvements in Target Fabrication for Laboratory Astrophysics Experiments at the University of Michigan

, D.C. MARION, R.P. DRAKE, C.C. KURANZ, A.J. VISCO, F.W. DOSS, M.J. GROSSKOPF, R.S. GILLESPIE, University of Michigan — Laboratory astrophysics seeks to study astrophysical phenomenon by modeling them in a micro-scale experiment, called a "target", which mimics the conditions and behavior of stellar phenomenon. Once built, the targets are transported to the Omega Laser Facility and placed in the laser chamber, where 5kJ of energy is fired onto a pinhead-sized area in order to create the necessary pressure required to launch the experiment. Collected data is then used to better understand the physics behind these various space phenomenon. Due to their extremely small size, targets must be built with a high degree of accuracy; therefore, continuously improving the process of target fabrication is crucial to experimental success. Some advancements in the target build process include more fully utilizing our machining capabilities, which allows for consistently cleaner, more accurately built targets. Another improvement is consolidating multiple functions into a single piece. This reduces the number of additional components, which reduces opportunities for error, as well as the overall build time. These changes have already been shown to improve our ability to collect successful data. *This research was sponsored by the NNSA through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA00064, and other grants and contracts.

JP8.00048 Experimental Study of Effects due to Perturbations on Boundary Conditions on Couette Flows

, F. MANLEY, H. JI, M. BURIN, E. SCHARTMAN, M. NORNBERG, A. ROACH, PPPL, MRI TEAM — When fluid flows between two independently rotating cylinders at low aspect ratios (the ratio of the height to the difference in radii), the flow is seen to deviate substantially from ideal Couette flow due to Ekman circulation along the end caps. In the case where the end caps are attached to the outer cylinder, fluid with less angular momentum is advected into the bulk flow, which decreases the mean velocity as predicted by the ideal case. In order to study the stability of Ekman circulation, an experiment was devised to perturb the Ekman boundary layer by modifying the inner cylinder. Water flows between an aluminum inner cylinder and acrylic outer cylinder and its velocity is measured using a Laser Doppler Velocimeter (LDV) scanned radially from underneath to obtain 2-D velocity profiles. When the inner cylinder is perturbed, the flow is closer to the ideal Couette case if Ekman circulation is reduced. The robustness of the Ekman layer along with flow discontinuities at the edges where the inner and outer cylinder meet will be studied against perturbations of varying magnitudes.

JP8.00049 A Smart Filtering Method for Space-Charge Dominated Beam Simulations[1]

, SEAN BARTZ, Xavier University and Indiana University, MARK HESS, Indiana University Cyclotron Facility — We present a "smart" filtering method that removes the small-wavelength noise in beam simulation programs which can occur due to numerical errors. This method utilizes Fourier transforms and a low-pass filtering scheme to remove noise from space-charge generated electric fields. In particular, for a uniform-density (beer can) beam distribution, we find the necessary amount of Fourier k-space for removing field errors while maintaining the electric field's maximum peak value and its full width at half maximum. The term "smart" refers to the method's applicability for general beam distributions which have equivalent root-mean-square sizes as the uniform-density case. We demonstrate the ability of the algorithm to filter the longitudinal and radial components of the electric field in both one dimension and two dimensions. This method has the potential to reduce computational run-time while maintaining a high level of accuracy, i.e. less than two percent field error.

[1]Research funded by NSF REU program

JP8.00050 ELECTRON AND ION BEAMS/SPACE CHARGE —

JP8.00051 Phase Space Tomography and Slice Emittance Measurement of Beams with intense Space Charge[1]

, DIKTYS STRATAKIS, RAMI KISHEK, KAI TIAN, RALPH FIORITO, IRVING HABER, BRIAN BEAUDOIN, MARK WALTER, MARTIN REISER, PATRICK O'SHEA, Institute for Research in Electronics and Applied Physics — We report a simple and portable tomographic method to map the beam phase space, which can be used in the majority of accelerators. The tomographic reconstruction process has first been compared with results from simulations using the particle-in-cell code WARP and the results show excellent agreement. Our diagnostic has also been successfully demonstrated experimentally on simple scaled set-up which uses high-current, low energy electron beams to study the transverse dynamics of beams in both emittance and space charge dominated regimes. Finally, using a fast (<5ns decay time) phosphor screen and a gated PIMAX2 ICCD camera we report slice tomographic measurements of transverse phase spaces over a beam pulse and conclude by deriving interesting physical insights on space charge dynamics.

[1]This work is funded by US Dept. of Energy grant numbers DE-FG02-94ER40855 and DE-FG02-92ER54178, and the office of Naval Research grant N00014-02-1-0914.

JP8.00052 Halo creation and propagation in the University of Maryland Electron Ring[1]

, CHRISTOS PAPADOPOULOS, University of Maryland, College Park, G. BAI, B. BEAUDOIN, I. HABER, R.A. KISHEK, P.G. O'SHEA, M. REISER, D. STRATAKIS, M. WALTER, UNIVERSITY OF MARYLAND ELECTRON RING TEAM — The University of Maryland Electron Ring (UMER) is a scaled low-energy electron machine, designed to access the intense regime of beam operation in particle accelerators. One of the phenomena that can arise during the transport of intense beams is the creation of halos around the beam core. This can significantly deteriorate the quality of the beam and complicate the maintenance of the facility. In this study, we use the WARP particle-in-cell code to numerically investigate a number of causes of halo in intense beams and the propagation of the halo downstream. In particular, we focus on the UMER beam, where halos have been observed and compare the simulation results to the experimental data.

[1]Work supported by the US Dept of Energy

JP8.00053 Measurement and Simulation of Source-Generated Halos in the University of Maryland Electron Ring (UMER)[1]

, I. HABER, S. BERNAL, R.B. FELDMAN, R.A. KISHEK, P.G. O'SHEA, C. PAPADOPOULOS, M. REISER, D. STRATAKIS, M. WALTER , University of Maryland, A. FRIEDMAN, D.P. GROTE, LLNL, J.-L. VAY, LBNL — An area of nonlinear beam physics that is important in a number of beam systems, and is inadequately understood, is the generation and evolution of beam halos. Study of beam halos therefore has served as one rationale for recent research on UMER. While it was expected that halo formation would primarily result from nonlinear dynamics during beam propagation, recent experiments and simulations have instead identified imperfections in the source geometry, particularly in the region near the emitter edge, as a potentially significant source of halo particles. The edge-generated halo particles, both in the experiments and the simulations are found to pass through the center of the beam a short distance downstream of the anode plane. Understanding the detailed evolution of these particle orbits is therefore important to designing any aperture to remove the beam halo. Both experimental data and simulations will be presented to illustrate the details of this process, as well as proposed means of mitigation.

[1]Work supported by the US DOE under contract Nos. DE-FG02-02ER54672 and DE-FG02-94ER40855 (UMD), and DE-AC02-05CH11231 (LBNL) and W-7405-ENG-48 (LLNL)

JP8.00054 Detection of Collective Beam Modes in the Paul Trap Simulator Experiment[1] , E.P. GILSON, M. CHUNG, R.C. DAVIDSON, M. DORF, P.C. EFTHIMION, R. MAJESKI, E.A. STARTSEV, Princeton Plasma Physics Laboratory, A.B. GODBEHERE, Cornell University — Experiments have been performed to excite and detect collective transverse symmetric and quadrupole modes ($m = 0, 2$) in the Paul Trap Simulator Experiment (PTSX). PTSX is a compact laboratory Paul trap that simulates a long, thin charged-particle bunch coasting through a kilometers-long magnetic alternating-gradient transport system by putting the physicist in the frame-of-reference of the beam. The transverse dynamics of particles in both systems are described by the same sets of equations – including nonlinear space-charge effects. The frequency spectrum of collective mode oscillations depends on the details of the distribution function, the focusing field strength, the self-field intensity parameter, and geometric effects such as the proximity of the conducting wall. These oscillations typically involve various combinations of the frequencies $\hat{\omega}_q$, $\hat{\omega}_p$, and $(\hat{\omega}_q^2 - \hat{\omega}_p^2/2)^{1/2}$ (where $\hat{\omega}_q$ is the average transverse focusing frequency and $\hat{\omega}_p$ is the plasma frequency) modified by geometric effects (r_p/r_w). Initial experiments focus on identifying collective modes whose signature will serve as a robust diagnostic for key properties of the beam, such as line density and transverse emittance. The experimental results are compared with the output of particle-in-cell simulations performed using the WARP code.

[1]This research is supported by the U.S. Department of Energy.

JP8.00055 Experimental verification of random error-induced beam degradation in high intensity accelerators using a compact Paul trap[1] , M. CHUNG, E.P. GILSON, R.C. DAVIDSON, P.C. EFTHIMION, R. MAJESKI, E.A. STARTSEV, Princeton Plasma Physics Laboratory — The effects of random errors in quadrupole magnets on intense beam propagation have been investigated in the Paul Trap Simulator Experiment (PTSX). The PTSX device is a compact linear Paul trap that can simulate the nonlinear transverse dynamics of intense beam propagation over large equivalent distances through an alternating-gradient (AG) transport lattice. The amplitude of the voltage waveform applied to the electrodes in the PTSX device corresponds to the quadrupole focusing field strength in an AG lattice system. Hence, by slightly modifying the voltage amplitude of the PTSX electrodes in every half focusing period, the effect of randomly distributed quadruploe focusing gradient error in high intensity accelerators can be effectively studied. Initial results show that the transverse beam emittance increases linearly with error amplitude and holding time. The experimental results are also compared with results obtained from 2D WARP simulations.

[1]This research was supported by DOE Contract DE-AC02-76-CHO3073.

JP8.00056 Beam plasma interaction in the solenoidal focusing of intense ion beams[1] , DALE WELCH, DAVID ROSE, THOMAS GENONI, Voss Scientific, LLC, PETER SEIDL, JOSH COLEMAN, PRABIR ROY, Lawrence Berkeley National Laboratory, IGOR KAGANOVICH, ADAM SEFKOW, Princeton Plasma Physics Laboratory — Extreme longitudinal and transverse bunching of space charge dominated ion beams is required to heat targets into the warm dense matter regime. Longitudinal bunching factors in excess of 70 with a several millimeter spot have been demonstrated on the 300-keV, 27-mA K+ ion beam Neutralized Drift Compression Experiment in rough agreement with particle-in-cell end-to-end simulations. To achieve the necessary spot size for target heating (< 1 mm), a strong final focus solenoid is currently being fielded. To neutralize the large perveance beam, a plasma with density greater than that of the beam must be injected into or produced within the solenoid. In this paper, we present theory and simulation of the neutralization of such an ion beam in a highly magnetized plasma. Beam neutralization and instability in the plasma are modeled in highly resolved simulations. The impact of instabilities and resulting turbulence on the focusing ion beam phase space is studied.

[1]This work was supported by the U.S. D.O.E. through PPPL and the HIFS-VNL

JP8.00057 Meter-Long Plasma Source for Heavy Ion Beam Charge Neutralization[1] , P.C. EFTHIMION, E.P. GILSON, R.C. DAVIDSON, Princeton Plasma Physics Lab, B.G. LOGAN, P.A. SEIDL, Lawrence Berkeley National Lab, W. WALDRON, Lawrence Bekeley National Lab — Plasmas are a source of unbound electrons for charge neutralizing intense heavy ion beams to focus them to a small spot size and compress their axial length. The source should operate at low neutral pressures and without strong externally-applied electric or magnetic fields. To produce long plasma columns, sources based upon ferroelectric ceramics with large dielectric coefficients have been developed. The source utilizes the ferroelectric ceramic $BaTiO_3$ to form metal plasma. The drift tube inner surface of the Neutralized Drift Compression Experiment (NDCX) is covered with ceramic material. High voltage (~ 8 kV) is applied between the drift tube and the front surface of the ceramics. A $BaTiO_3$ source comprised of five 20-cm-long sources has been tested and characterized, producing relatively uniform plasma in the 5x10^{10} cm^{-3} density range. The source has been integrated into the NDCX device for charge neutralization and beam compression experiments. Initial beam compression experiments yielded current compression ratios ~ 120. Future research will develop longer and higher density sources to support beam compression experiments for high energy density physics applications.

[1]Work support by US Department of Energy.

JP8.00058 Warm-fluid theory of a thermal equilibrium for a charged-particle beam in a periodic quadrupole magnetic focusing field[1] , KSENIA SAMOKHVALOVA, JING ZHOU, CHIPING CHEN, MIT/PSFC — A new warm-fluid thermal equilibrium theory is developed for charged-particle beam propagation in a periodic quadrupole magnetic focusing field. Warm-fluid equilibrium equations are solved in the paraxial approximation. The equation of state for the thermal equilibrium is adiabatic. The beam density profile, the beam envelope equations and self-consistent Poisson equation are derived. The numerical algorithm for solving the self-consistent Poisson equation is discussed. Examples of thermal beam equilibrium will be presented for low intensity and high intensity beams propagating in periodic quadrupole magnetic focusing fields.

[1]Research supported by Department of Energy, Office of High-Energy Physics, Grant No. DE-FG02-95ER40919, and Air Force Office of Scientific Research, Grant No. FA9550-06-1-0269.

JP8.00059 Perturbative Particle Simulation Studies of Periodically Focused Intense Charged Particle Beams[1] , WEIHUA ZHOU, HONG QIN, RONALD DAVIDSON, Princeton Plasma Physics Laboratory — High intensity charged particle beam propagation in a periodic focusing lattice has been studied numerically using a model in which the beam equilibrium and dynamical behavior are described self-consistently by the nonlinear Vlasov-Maxwell equations. To carry out this investigation, the Beam Equilibrium Stability and Transport (BEST) code, which uses a 3D low-noise perturbative particle simulation method, has been extended to periodic-focusing systems. The scheme begins with a smooth-focusing lattice, which is the smooth-focusing approximation for the periodic lattice, and adiabatically replaces the smooth-focusing lattice by the periodic-focusing lattice. Using this approach, periodic-focusing solenoidal configurations have been investigated using a slow turn-on time to minimize beam mismatch, and periodic-focusing quadrupole configurations have also been studied using this approach.

[1]This research was supported by the U.S. DoE contract #DE-AC02-76-CHO3073.

JP8.00060 Acceleration Gap Effects on the Longitudinal Compression of Intense Ion Beams in the Neutralized Drift Compression Experiment[1] , ADAM SEFKOW, RONALD DAVIDSON, Princeton Plasma Physics Laboratory — Longitudinal compression of space-charge-dominated ion beams to high currents in nanosecond pulses for warm dense matter and heavy ion fusion applications is achieved by imposing a time-dependent velocity tilt to the charge bunch across the acceleration gap of a linear induction accelerator. The subsequent neutralization of the beam by a pre-formed plasma allows the intense charge bunch to compress above the traditional space-charge limit for quiescent propagation and longitudinal focusing. The detailed physics and implications of acceleration-gap effects and focusing aberration on optimum current compression are reviewed. Quantitative examples using particle-in-cell simulations explore the dependency of the axial compression on effects such as the finite-size acceleration gap, voltage waveform, and the beam's initial temperature, pulse length, intended fractional velocity tilt, kinetic energy uncertainty, and distribution function.

[1]Research supported by the U.S. Department of Energy under the auspices of the Heavy Ion Fusion Science Virtual National Laboratory

JP8.00061 Nonlinear Delta-f Particle Simulations of Energy-Anisotropy Instabilities in High-Intensity Bunched Beams[1] , HONG QIN, RONALD DAVIDSON, EDWARD STARTSEV, Princeton Plasma Physics Lab — The self-consistent Vlasov-Maxwell equations and a generalized delta-f particle simulation algorithm are applied to high- intensity finite-length charge bunches. For bunched beams with anisotropic energy, there exists no exact kinetic equilibrium because the particle dynamics do not conserve transverse energy and longitudinal energy separately. A reference state in approximate dynamic equilibrium has been constructed theoretically. The electrostatic Harris instability driven by strong energy anisotropy relative to the reference state have been simulated using the generalized delta-f algorithm for bunched beams. The observed growth rates are larger than those obtained for infinitely-long coasting beams. The growth rate decreases for increasing bunch length to a value similar to the case of a long coasting beam. For long bunches, the instability is axially localized symmetrically relative to the beam center, and the characteristic wavelength in the longitudinal direction is comparable to the transverse dimension of the charge bunch. A smooth, automatic-switching scheme between the delta-f and total-f methods is being used to simulate the nonlinear phase of the instability.

[1]Research supported by the U. S. Department of Energy.

JP8.00062 Filamentation of a Radially Converging Heavy Ion Beam in a Background Plasma with External Solenoidal Magnetic Field[1] , EDWARD STARTSEV, RONALD DAVIDSON, PPPL, DALE WELCH, DAVID ROSE, Voss Scientific, Albuquerque NM — Heavy ion inertial fusion and high energy density physics experiments with intense heavy ion beams require the transverse focusing of the ion beam pulse onto a small focal spot. Plasma is used to neutralize the beam's space charge to achieve maximum compression. Unfortunately, a heavy ion beam propagating in a background plasma may be subject to the filamentation instability. The beam can be severely disrupted by the instability before it reaches the target. An external solenoidal magnetic field can be used to stabilize the instability. This paper analyzes the influence of both the transverse convergence and an applied solenoidal magnetic field on the filamentation instability of a cold heavy ion beam propagating in neutralizing background plasma. We employ the WKB approach to analyze the space-time development of the instability and compare it with the results of simulations using the particle-in-cell code LSP. The results of the investigations identify the instability growth rates, levels of saturation, and the conditions for quiescent beam propagation.

[1]Research supported by the U. S. Department of Energy.

JP8.00063 Controlling Charge and Current Neutralization of an Ion Beam Pulse in a Background Plasma by Application of a Small Solenoidal Magnetic Field , IGOR D. KAGANOVICH, EDWARD A. STARTSEV, ADAM B. SEFKOW, RONALD C. DAVIDSON, Princeton Plasma Physics Laboratory — Propagation of an intense charged particle beam pulse through a background plasma is a common problem in astrophysics and plasma applications. The plasma can effectively neutralize the charge and current of the beam pulse, and thus provides a convenient medium for beam transport. The application of a small solenoidal magnetic field can drastically change the self-magnetic and self-electric fields of the beam pulse, thus allowing effective control of the beam transport through the background plasma. An analytical model is developed to describe the self-magnetic field of a finite-length ion beam pulse propagating in a cold background plasma in a solenoidal magnetic field. The analytical studies show that the solenoidal magnetic field starts to influence the self-electric and self-magnetic fields when $\omega_{ce} > \omega_{pe}\beta_b$, where $\omega_{ce} = eB/m_e c$ is the electron gyrofrequency, ω_{pe} is the electron plasma frequency, and $\beta_b = V_b/c$ is the ion beam velocity relative to the speed of light. Analytical formulas are derived for the effective radial force acting on the beam ions, which can be used to minimize beam pinching. The results of analytical theory have been verified by comparison with the PIC simulation results, which show good agreement.

JP8.00064 New Spectral Method for Halo Particle Definition for Intense Charged Particle Beams[1] , MIKHAIL DORF, RONALD DAVIDSON, EDWARD STARTSEV, Princeton Plasma Physics Laboratory — Spectral analysis of a mismatched charged particle beam has been utilized in particle-in-cell simulations performed with the WARP code. It is shown that the betatron frequency distribution function of a mismatched space-charge-dominated beam has a bump-on-tail structure attributed to beam halo particles. A new spectral method for halo particle definition is proposed in this work that provides the opportunity to carry out a quantitative analysis of halo particle production by beam mismatch. Furthermore, the spectral analysis of the mismatch relaxation process provides important insights into the emittance growth attributed to the halo formation and the core relaxation processes. Numerical simulations are performed using the smooth focusing approximation, which describes the average effects of an alternating-gradient lattice, and by using a full quadrupole focusing field model, taking into account the effects of the alternating-gradient quadrupole field.

[1]Research supported by the U.S. Department of Energy.

JP8.00065 Optimized Photonic Crystal Accelerating Cavities , CARL BAUER, GREGORY WERNER, Center for Integrated Plasma Studies, University of Colorado, Boulder, CO, JOHN CARY, Center for Integrated Plasma Studies, University of Colorado, Boulder, CO and Tech-X Corp., Boulder, CO — Photonic crystal (PhC) cavities may provide a useful replacement for metallic accelerating cavities used in linacs today. The main advantage of PhC cavities lies in their ability to suppress higher-order modes (HOMs). Because of the frequency bandgaps found in PhCs, certain disruptive HOMs can be made to propagate out of a PhC structure. One disadvantage with PhC cavities, however, is their size. For a PhC cavity, many layers of scattering elements are needed to attain Q-values comparable to metallic cavities, because of the radiative losses from the trapped mode. In response, we show how optimizing the positions and size of the individual scatterers can increase the maximum Q due to radiation losses by ~ 2 orders of magnitude for a specified number of scatterers, and thus decrease the physical extent required for cavities of this type. We present here examples of optimized PhC accelerating cavities and discuss their individual resonant mode spectra. We also show results from simulations of particle beams passing through these cavities without significant excitation of HOMs.

JP8.00066 Photonic Crystal Structures for Particle Acceleration , GREGORY R. WERNER, University of Colorado, JOHN R. CARY, University of Colorado/Tech-X Corp., CARL A. BAUER, University of Colorado — An electromagnetic resonant cavity with only a single mode can be created using a photonic crystal structure to trap the fields. Because photonic crystals can reflect only radiation within a small frequency range, they can trap only the fundamental mode of a cavity, while higher frequency modes propagate out through the crystal. The absence of higher modes can benefit accelerator cavities, in which higher order modes (wakefields) excited by the beam degrade the beam quality. We examine the fields of an electron beam in a photonic crystal cavity using computer simulations.

JP8.00067 Simulations of neutral loading process in ECR sources[1] , PETER MESSMER, DAVID FILLMORE, KEVIN PAUL, PAUL MULLOWNEY, ANDREY SOBOL, Tech-X Corporation, DAMON TODD, DANIELA LEITNER, LBNL, DAVID BRUHWILER, Tech-X Corporation — High intensity, high charge-state beams for a broad variety of ions are a requirement for next-generation heavy-ion beam accelerators. As the intensities produced by current Electron Cyclotron Resonance (ECR) sources insufficient for many ions, the ion beam production has to be optimized. Efficient loading of the neutrals into the ECR plasma is one of the key elements for optimizing the ion beam production. Kinetic simulations provide a means to understanding where along the interior walls the uncaptured metal atoms are deposited and, hence, how to optimize loading of the metal into the ECR plasma. We are currently extending the plasma simulation framework VORPAL with models to investigate effective loading of heavy metals into ECR ion sources via alternate mechanisms, including vapor loading, ion sputtering and laser ablation. Here we will present the models, simulation results of vapor loading and initial comparisons with experiments at the VENUS source at LBNL.

[1]Work supported by the U.S. DOE Office of Science, Office of Nuclear Physics, under grant DE-FG02-05ER84173.

JP8.00068 Development of a 25 keV Ion Beam Source for Fast-Ion Studies on the Large Plasma Device[1] , S.K.P. TRIPATHI, P. PRIBYL, W. GEKELMAN, Z. LUCKY, Department of Physics and Astronomy, UCLA — A helium ion beam source (25 kV, 3 A) has been constructed for studying the fast-ion physics on the large plasma device (LAPD). The source has been designed to match the ion beam speed with the Alfvén speed in the LAPD plasma. The ion beam will be injected at a variety of pitch angles into the LAPD. The ion-beam source has an inductive RF source to produce $\approx 10^{19}$ m^{-3} helium plasma in a ceramic dome (volume: ≈ 0.04 m^3). The beam is accelerated using a rectangular (8 cm x 8 cm), multi-aperture, three-grid system. A pulsed DC power supply (25 kV, 4 A) has been developed to deliver the acceleration voltage to the grids during the time interval (0.1 – 2.0 ms, rep rate: 1 Hz) of the beam injection. A EUV grazing incidence monochromator (for the Doppler-shift measurements) and Langmuir probes are main diagnostic tools. The source is presently being conditioned in a test facility. We plan to present the initial results on the characterization of the ion-beam and its interaction with the LAPD plasma.

[1]Work supported by US DOE and NSF for the fast-ion campaign at the Basic Plasma Science Facility, UCLA

JP8.00069 Transport of Fast Ions Modulated by Shear Alfvén Waves[1] , YANG ZHANG, HEINZ BOEHMER, WILLIAM HEIDBRINK, ROGER MCWILLIAMS, UC Irvine, TROY CARTER, DAVID LENEMAN, STEPHEN VINCENA, BRIAN BRUGMAN, WALTER GEKELMAN, UCLA, UC IRVINE TEAM, UCLA COLLABORATION — The interaction of fast particles with Alfvén instabilities is important in magnetic fusion devices and natural plasmas. In this experiment, shear Alfvén waves (SAW) modulate fast ion transport through Doppler shifted cyclotron resonance, in addition to the classical collisional diffusion. A Li^+ ion source is inserted in the LArge Plasma Device (LAPD) with ion energy up to ∼2000 eV, detected by a collimated fast ion energy analyzer. RF antennas launch waves with amplitude of \delta B/B ∼ 0.1% that propagate along the machine axis. When launched in (out of) phase with the perpendicular wave electric field, fast ions gain (lose) energy from (to) the wave. A ∼10% increase in the beam radial width and beam signal modulation at SAW frequency are observed. These fast ion transport phenomena peak near the predicted resonance condition. ($\omega_{Alfv\acute{e}n} - k_z v_z = \omega_{fast-ion}$)

[1]Work supported by DOE DE-FG02-03ER54720.

JP8.00070 Numerical Optimization Studies of the NDCX Induction Accelerator[1] , ENRIQUE HENESTROZA, SONIA IBARRA, LBNL — The Heavy Ion Fusion Science Virtual National Laboratory is designing the Neutralized Drift Compression Experiment (NDCX) at the Lawrence Berkeley National Laboratory. NDCX will help develop novel, still unexplored beam manipulation techniques in order to establish the physics limits on compression of heavy ion beams for creating high energy density matter and fusion ignition conditions. The NDCX components include an injector that delivers a lithium ion beam, and an accelerator that boosts the energy to 2.8 MeV. Further beam manipulations will compress the beam to a final spot radius of less than 1 mm and a pulse length of 1 ns. In order to reach those final parameters, it is required to extract a high brightness beam and minimize the transverse and longitudinal emittance growth along the accelerator. We will present numerical optimization studies of the injector which is based on the Accel-Decel concept, and the accelerator which is based on acceleration by induction gaps.

[1]This Research was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

JP8.00071 Initial Operation of Pulsed Ion Beam system for NBI of All Japan ST Program , NOBORU YAMAGUCHI, HIROTAKA KAJIYA, NAOKI TAKAHASI, TOMOHIKO ASAI, TSUTOMU TAKAHASI, Nihon univ., HEIZOU IMANAKA, MASAKATSU MINAMI, YASUSI ONO, YUICHI TAKASE, Univ. Tokyo, KOUNOSUKE SATO, Kyushu Univ., NIHON UNIV. TEAM, UNIV. TOKYO TEAM, KYUSHU UNIV. TEAM — The UTST experiment at Univ. Tokyo is expected to produce ultra high-beta Spherical Tokamak (ST) using mega-watt heating power of ST merging/reconnection. A key issue after the formation is to maintain the produced ultra-high-beta ST over 100 Alfven times for its stability research. The following three heating methods has been arranged for the sustainment experiment: (1) advanced RF heating method developed in TST-2, (2) low-cost pulsed neutral beam injection (NBI) system under development and (3) intermittent merging/ reconnection by TS-3 and 4. The NBI system for UTST was designed to realize (1) low voltage (15kV for low-field side of a ST) and high current (20A), (2) maintenance-free, (3) low-costA SUS washer gun has been employed for the first time to realize the maintenance-free plasma (ion) source, in sharp contrast with the conventional filament type plasma source. In the initial operation of plasma source, the electron and ion density profile suitable for the ion beam extraction had been observed. Now evaluation of characteristics of the extracted plasma has been performed. Further results of the developed NBI will be presented

JP8.00072 Further studies of a simple gyrotron model equation , JULIANA PEREZ, HAROLD WEITZNER, New York University — Work with other authors, *J. Phys. A: Math. Theor.* **40**, 2203 (2007), is extended. Analytic and computational methods are applied to examine desirable start-up conditions in a gyrotron and to minimize deleterious bunching effects. Analysis permits extensive, but incomplete exploration of the dynamics, while computation with the simple model provides essential, more complete results. Several of the conclusions of the cited paper are significantly modified.

JP8.00073 DIII-D I —

JP8.00074 Recent DIII-D Research in Support of ITER[1] , M.R. WADE, General Atomics, DIII-D NATIONAL TEAM — The DIII-D research team has made several recent contributions that are impacting the design of key components for ITER. Using criteria determined from recent DIII-D experiments showing the importance of island overlap in the edge, researchers have evaluated various non-axisymmetric coil configurations for ITER. DIII-D experiments have established criteria for stabilization of the most serious instabilities in ITER: resistive wall modes (RWMs) and neoclassical tearing modes (NTMs). Analysis suggests that a small level of toroidal rotation is sufficient to stabilize RWMs even at β_N=4. DIII-D experiments were instrumental in the choice of an improved ECCD mirror design for ITER, enabling the ability to simultaneously stabilize the m=3/n=2 and m=2/n=1 NTMs with ∼10 MW in ITER. Recent studies on DIII-D simulating the current ramp phase in ITER indicate a risk of peaked current density profiles and an associated susceptibility to vertical instability. Results of other research on disruption mitigation using massive gas injection and on the choice of plasma facing materials in ITER will also be presented.

[1]Work supported by the US DOE under DE-FC02-04ER54698.

JP8.00075 Understanding Magnetic Field Error Correction in DIII-D[1] , M.J. SCHAFFER, R.J. LA HAYE, E.J. STRAIT, General Atomics, J-K. PARK, J.E. MENARD, PPPL, A.H. BOOZER, Columbia U. — A comparison was made between the measured DIII-D magnetic field error and an ideal MHD plasma response model. New measurements of TF coil errors reduced the bounds of unknown errors. Empirical error corrections for DIII–D standard left-handed-pitch plasmas were refined, and a new empirical correction was developed for right-handed-pitch plasmas. Empirical corrections were analyzed by the new Ideal Perturbed Equilibrium Code, which computes the linear free-boundary plasma response to prescribed external error and/or correction fields in real geometry. This analysis explained the paradox of why the DIII-D C-coil empirical correction is ∼3 times the error field on a vacuum field basis: the plasma strongly modifies the error and correction fields differently, and the total fields actually come to partial cancellation. The theory provides guidance for error correction with imperfectly matched fields. Separately, a short proof of principle experiment showed that further improvement (locked mode avoidance) is possible if the remaining TF coil current feed error were reduced.

[1]Work supported by U.S. DOE under DE-FC02-04ER54698.

JP8.00076 Low Frequency Response of Plasma to MHD Perturbations[1] , M.S. CHU, General Atomics, Y.Q. LIU, Chalmers University — MHD stability of the plasma depends critically on the frequency and wave length of the perturbation. Future tokamaks are expected to operate in regimes where the external macro-scale perturbations have much lower frequencies than the intrinsic dynamical time scales of the particles [1]. This situation calls for a detailed re-examination of the assumptions on previous models of the response of the plasma to MHD perturbations [2]. The kinetic formulation of MHD response [3] is examined numerically in this work. The energy and momentum flux across the plasma surface is expressed in terms of the MHD perturbations. Implication on the stability and plasma response [4] relevant for the resistive wall mode, with its time scale dramatically reduced by the external resistive wall, is discussed.

[1] B. Hu, *et al.,* Phys. Plasmas **12**, 057301 (2005).
[2] A. Bondeson and M.S. Chu, Phys. Plasmas **3**, 3013 (1996).
[3] T.M. Antonsen, Jr. and Y.C. Lee, Phys. Fluids **25**, 132 (1982).
[4] Y.Q. Liu, *et al.,* Phys. Plasmas **7**, 3681 (2000).

[1]Supported by the US DOE under DE-FG03-95ER54309.

JP8.00077 Development of State-Space Model-Based Kalman Filter for n≥1 Resistive Wall Mode (RWM)[1] , Y. IN, J.S. KIM, J. KIM, FAR-TECH Inc., D.A. HUMPHREYS, G.L. JACKSON, R.D. JOHNSON, R.J. LA HAYE, E.J. STRAIT, M.L. WALKER, General Atomics, A.M. GAROFALO, H. REIMERDES, Columbia U., M. OKABAYASHI, PPPL, E. SCHUSTER, Lehigh U. — While significant progress has been made for n =1 RWM identification and control, it is now predicted that $n > 1$ RWMs could appear even after the n =1 RWM is suppressed. Algorithm development, as well as diagnostic capability enhancement, is being done in order to identify the $n = 2$ or 3 RWMs in the presence of a stabilized n =1 RWM for DIII-D. Specifically, taking advantage of the successful development of the Kalman filter to discriminate ELM noise from an n =1 RWM [1], a more advanced Kalman filter is being developed to detect both n=1 and $n > 1$ RWMs. Noise characterization and modeling is deemed critical to determine the optimized Kalman gain. This multi-mode state-space model will also serve as a basis to design a model-based RWM feedback controller. [1] Y. In *et al.*, Phys. Plasmas **13**, 062512 (2006).

[1]Supported by the US DOE under DE-FG02-ER83657, DE-FC02-04ER54698, DE-FG02-89ER53297, DE-AC02-76CH03073, and DE-FG02-92ER54141.

JP8.00078 Numerical Analysis of the 2D Newcomb Equations for the Resistive Wall Modes (RWMs)[1] , J. SHIRAISHI, ORISE, M.S. CHU, General Atomics, S. TOKUDA, N. AIBA, JAEA, M. FURUKAWA, U. Tokyo — Stabilization of the RWM is one of the most important design issues for future reactors operated in the advanced tokamak regime. The MARG2D [1] stability code, which solves the 2D Newcomb equations [2], is extended to study the stability of the RWM. The linear dynamics of the perturbations in RWM obeys the functional [3] $\delta W_r = \delta W_p + \delta W_{IV} + \delta W_{OV} + D_w = 0$, where δW_p is the plasma potential energy, $\delta W_{IV(OV)}$ the vacuum magnetic energy inside (outside) the resistive wall, and D_w the energy dissipated in the resistive wall. In MARG2D, δW_p and δW_{OV} are given by bilinear functionals of the displacements and the perturbed magnetic field. δW_{IV} is described by a scalar potential and solved by the finite element method. Results from the MARG2D code are compared with those given in [3]. The solutions of the eddy current on the resistive wall will also be compared with new WKB solutions. [1] N. Aiba, *et al.,* Plasma Phys. Control. Fusion **46**, 1699 (2004). [2] S. Tokuda and T. Watanabe, Phys. Plasmas **6**, 3012 (1999). [3] M.S. Chu, *et al.,* Nucl. Fusion **43**, 441 (2003).

[1]Supported by the US DOE under DE-AC05-76OR00033 and DE-FG03-95ER54309.

JP8.00079 Observation of n>1 Mode During ELM-Driven RWM Experiments in DIII-D[1] , J. KIM, Y. IN, J.S. KIM, FAR-TECH Inc., M. OKABAYASHI, PPPL, E.J. STRAIT, General Atomics, A.M. GAROFALO, H. REIMERDES, Columbia U. — In recent resistive wall mode (RWM) experiments in DIII-D, edge localized modes (ELMs) were found to trigger RWMs in high rotation plasmas, which are well above the rotation threshold [1]. Interestingly, the ELM-induced n=1 perturbations are almost always accompanied by significant amounts of n=3 modes. While an n=1 ELM-driven RWM grows but can be suppressed by active feedback, the influence of n=3 mode needs to be investigated. A clear example that an ELM-driven n=3 mode grew without being hindered by n=1 feedback will be presented. It is noteworthy that the n=3 mode appeared to cause β and rotation collapses, similar to n=1 RWM. Detailed MHD analysis is in progress to investigate whether the n=3 mode is attributable to n=3 RWM in the vicinity of n=1 wall-stabilized plasmas [2]. We will discuss the stability calculation results and the details of the n=3 mode observation. [1] E.J. Strait, *et al.,* Bull. Am. Phys. Soc. **50**, 79 (2005). [2] Y. In, *et al.,* to be submitted for publication.

[1]Supported by US DOE under DE-FG02-03ER83657, DE-FC02-04ER54698, DE-FG02-89ER53297, and DE-AC02-76CH03073.

JP8.00080 Robust Control of Resistive Wall Mode in DIII-D Based on Eigenmode Approach[1] , J. DALESSIO, E. SCHUSTER, LeHigh University, D.A. HUMPHREYS, M.L. WALKER, General Atomics, Y. IN, J.S. KIM, FAR-TECH Inc. — Control of the resistive wall mode (RWM) is a major focus of the DIII-D experimental program. The FAR-TECH DIII-D/RWM model represents the plasma surface as a toroidal current sheet and represents the wall using an eigenmode approach [1]. The magnitude and phase of the RWM plasma deformation is determined from a set of 22 poloidal field probes and saddle loops, and 12 in-vessel coils are used to oppose the deformation. The resulting model is reformulated into a robust control framework, with a parameter that maps to the growth rate of the system modeled as an uncertain parameter. A robust controller that stabilizes the system for a range of practical growth rates is proposed, tested through simulations, and compared to other control techniques. Implications for experimental implementation and use are discussed. [1] Y. In, *et al.,* Phys. Plasma **13**, 062512 (2006).

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), the NSF CAREER award program (ECCS-0645086), and the US DOE under DE-FG02-92ER54141, DE-FC02-04ER54698, and DE-FG02-03ER83657.

JP8.00081 Study of RWM Stabilization by Plasma Rotation Using Active MHD Spectroscopy[1] , H. REIMERDES, A.M. GAROFALO, M.J. LANCTOT, G.A. NAVRATIL, Columbia U., M.S. CHU, G.L. JACKSON, R.J. LA HAYE, E.J. STRAIT, General Atomics, Y. LIU, Chalmers U., M. OKABAYASHI, PPPL — Active MHD spectroscopic measurements have been used to probe the stability of the n=1 and n=2 kink modes in various DIII-D scenarios. The response of the plasma to externally applied slowly rotating non-axisymmetric fields, measured with magnetic field sensors, yields damping rates and mode rotation frequencies. The measurements show the transition from an ideal MHD stable plasma to a weakly damped resistive wall mode (RWM) at the ideal MHD, no-wall stability limit. Active MHD spectroscopy also tests kinetic theory, which is thought to be responsible for the observed RWM stabilization by plasma rotation. In contrast to measurements of the rotation threshold, which is likely caused by a nonlinear interaction of residual error fields with the weakly damped RWM, the spectroscopic technique at sufficiently low amplitude can be directly compared to linear predictions.

[1]Supported by the US DOE under DE-FG02-89ER53297, DE-FC02-04ER54698, and DE-AC02-76CH03073.

JP8.00082 Challenges for Robust Feedback Stabilization of ELM-Driven Resistive Wall Mode (RWM)[1] , M. OKABAYASHI, H. TAKAHASHI, PPPL, A.M. GAROFALO, H. REIMERDES, M.J. LANCTOT, Columbia U., G.L. JACKSON, R.J. LA HAYE, E.J. STRAIT, GA, Y. IN, J. KIM, FAR TECH Inc. — The RWM can be stabilized by modest plasma rotation. However, even when plasma rotation is well above the critical value, MHD activities such as ELMs and Fishbones excite RWMs. Feedback plays several crucial roles against RWM onset. Minimizing the amplification of residual error fields due to MHD events is the first necessary step for providing robust feedback RWM stabilization. Below the no-wall β_N limit, feedback can reduce the residual n=1 RWM amplitude and consequently the amplification is reduced as indicated by the edge T_i. Near the high β_N operational limit, ELM events suddenly increase the amplitude of stable RWM resonating with residual error field, presumably triggered by the n=1 component of ELM or by the rapid change of the RWM mode pattern during ELMs. The existence of finite amplitude leads to fast unstable RWM growth. When the feedback can completely reduce the resonant process, high β plasmas remain stable.

[1]Supported by the US DOE under DE-AC02-76CH03073, DE-FG02-89ER53297, DE-FC02-04ER54698, and DE-FG03-99ER82791.

JP8.00083 Excitation of Resistive Wall Mode Instabilities by Transient MHD Events in DIII-D[1] , E.J. STRAIT, G.L. JACKSON, R.J. LA HAYE, General Atomics, M. OKABAYASHI, H. TAKAHASHI, PPPL, A.M. GAROFALO, H. REIMERDES, M.J. LANCTOT, Columbia U., Y. IN, J. KIM, FAR TECH Inc. — The resistive wall mode (RWM) often limits the performance of high-beta plasmas that rely on wall stabilization of low-n kink instabilities. The RWM can be stabilized by plasma rotation, but DIIID experiments show that even discharges with significant rotation are sometimes observed to develop a large-amplitude RWM immediately following an edge-localized mode (ELM) or other transient MHD event. This is thought to be the result of a nonlinear process in which the ELM resonantly drives the stable RWM to a finite amplitude, followed by magnetic braking of the plasma rotation. Open issues include the importance of magnetic shielding by the rotating plasma, the question of whether or not the RWM develops a positive growth rate during this process, and the possible role of scrape-off layer currents. Experimental results will be compared with a simple 0-D model.

[1]Supported by the US DOE under DE-FC02-04ER54758, DE-AC02-76CH03073, and DE-FG02-89ER53297.

JP8.00084 Sawtooth Suppression by Tearing Modes in Hybrid Plasmas on DIII-D[1] , C.C. PETTY, P.A. POLITZER, GA, W.W. HEIDBRINK, UCI, R. NAZIKIAN, PPPL, S.L. ALLEN, LLNL — Hybrid discharges have the remarkable property that the m/n=3/2 neoclassical tearing mode (NTM) raises the central safety factor (q_0) above unity and suppresses sawteeth. Experiments on DIII-D are trying to distinguish between several sawtooth suppression mechanisms. One mechanism that can be tested for is the redistribution of the beam ions by the 3/2 NTM, which would increase the off-axis neutral beam current drive (NBCD). The NBCD profile can be determined from the evolution of the poloidal flux measured by motional Stark effect (MSE) polarimetry. Also, the fast ion D_α (FIDA) diagnostic can measure the fast ion density profile for hybrid discharges with and without the 3/2 NTM. Another analysis tool is TRANSP simulations of the current profile evolution, which shows that diffusion of the beam ions is unlikely to raise q_0 above 1. Other possible sawtooth suppression mechanisms are hyper-resistivity, counter current drive in the plasma core via a coupling between the 3/2 NTM and a 2/2 sideband, and magnetic flux pumping.

[1]Work supported by US DOE under DE-FC02-04ER54698, SC-G903402, DE-AC02-76CH03073, and W-7405-ENG-48.

JP8.00085 Flow Shear and Tearing Stability in DIII-D[1] , R.J. LA HAYE, General Atomics, D.P. BRENNAN, U. Tulsa, R.J. BUTTERY, UKAEA-Culham, S. KRUGER, Tech-X Corp., D. CHANDRA, D. RAJU, A. SEN, Inst. for Plasma Research, FOR THE DIII-D TEAM — The reorientation of one neutral beam in DIII-D from co to counter injection has allowed tests of the effects of rotation on tearing stability. It is found that reduced plasma rotation and flow shear has a destabilizing effect. Existing modes get bigger. Otherwise stable modes are destabilized, i.e. the stable beta limit is lowered. Experimental examples in the saw-teething H-mode, the hybrid scenario, and the advanced tokamak will be presented. A significant level of stabilizing flow shear is of the order of the inverse of the product of the local magnetic shear length L_s and the Alfvén time τ_A; removing this flow shear by going from all co to near balanced injection decreases the tearing stability. Preliminary experimental analysis suggests that the relative sign of the flow shear and the magnetic shear also plays a role. The literature on the theory of tearing and flow will be reviewed. New studies of the effects of flow shear on tearing both analytically and with codes are in development.

[1]Supported by the US DOE under DE-FC02-04ER54698.

JP8.00086 Behavior of Escaping Fast Ions From DIII-D Tokamak[1] , Y.B. ZHU, W.W. HEIDBRINK, University of California, Irvine — The behavior of escaping fast ions from DIII-D Tokamak is investigated. Two pairs of thin foil Faraday collectors provide the energetic ion loss signals from the co/counter plasma current directions. The data are compared with neutron flux and fast ion deuterium alpha (FIDA) measurements. Comparative studies show that the signals are correlated with toroidal field and certain plasma parameters, such as plasma current, loop voltage, temperature and rotation. Further studies on the modulation of prompt ion loss induced by neutral beam injection, and enhanced fast ion loss from ion cyclotron radio frequency and MHD are reported. The secondary electron emission effect, which is believed to be responsible for the negative signal from blind background foil [1], is observed and qualitatively proven by active foil biasing experiments.
[1] M. Isobe, *et al.,* Rev. Sci. Instrum. **77**, 10F508 (2006).

[1]Supported by the US DOE under SC-G903402 and DE-FC02-04ER54698.

JP8.00087 Reversed Shear Alfvén Eigenmode Stabilization by Localized Electron Cyclotron Heating[1] , M.A. VAN ZEELAND, J. LOHR, General Atomics, W.W. HEIDBRINK, University of California, Irvine, R. NAZIKIAN, W.M. SOLOMON, N.N. GORELENKOV, G.J. KRAMER, PPPL, M.E. AUSTIN, U. Texas, T.L. RHODES, UCLA, C. HOLCOMB, M.A. MAKOWSKI, LLNL, G.R. MCKEE, U. Wisconsin, S.E. SHARAPOV, UKAEA — Reversed shear Alfvén eigenmode (RSAE) activity in DIII-D is observed to be stabilized by electron cyclotron heating (ECH) near the minimum of the safety factor (q_{min}) in neutral beam heated discharges with reversed magnetic shear. The degree of RSAE stabilization and the volume averaged neutron production (S_n) are highly dependent on ECH deposition location relative to q_{min}. Ideal MHD simulations predict RSAE existence during ECH, indicating that the mode disappearance is due to kinetic effects not taken into account by the ideal MHD model. While discharges with ECH stabilization of RSAEs have higher S_n than discharges with significant RSAE activity, neutron production remains strongly reduced (up to 60%), indicating the bulk of the deficit is not due to RSAEs alone.

[1]Supported by the US DOE under DE-FC02-04ER54698, SC-G903402, DE-AC02-76CH03073, DE-FG03-97ER54415, DE-FG02-01ER54615, W-7405-ENG-48, and DE-FG02-89ER53296.

JP8.00088 Central Flattening of the Fast-Ion Profile in Reversed-Shear Discharges With Alfvén Eigenmode Activity[1] , W.W. HEIDBRINK, Y. LUO, C. MUSCATELLO, UC-Irvine, N.N. GORELENKOV, R.B. WHITE, PPPL, M.A. VAN ZEELAND, GA, G. VLAD, Euratom-ENEA — Neutral beam injection into a plasma with reversed shear produces a rich spectrum of Alfvén eigenmodes (AE) in DIII-D. Application of fast-ion D_α (FIDA) spectroscopy shows that the central fast-ion profile is anomalously flat in the inner half of the discharge. Neutron and equilibrium measurements corroborate the FIDA data. The temporal evolution of the current profile is strongly modified. Calculations by the ORBIT code do not explain the observed fast-ion transport for the measured mode amplitudes. A simulation of this discharge with the HMGC code suggests that transient energetic particle modes may be primarily responsible for the fast-ion transport, while the experimentally obvious toroidal AE (TAE) and reversed shear AE (RSAE) may be relatively unimportant. A search for the predicted energetic particle modes is planned. An empirical study of the correlation of profile flattening with varying amounts of Alfvén activity in different discharges will also be presented.

[1]Supported by US DOE under SC-G903402, DE-AC02-76CH03073, and DE-FC02-04ER54698.

JP8.00089 First Current and Radial Electric Field Profile Measurements using the Full Co-Plus Counter-Beam Motional Stark Effect Diagnostic on DIII-D[1] , C.T. HOLCOMB, M.A. MAKOWSKI, S.L. ALLEN, W.H. MEYER, Lawrence Livermore National Laboratory — The motional Stark effect (MSE) diagnostic on DIII-D has been expanded to include 24 additional channels viewing a neutral beam injected counter to the direction of the beam viewed by the existing MSE system. Using data collected from a variety of discharge types, we compare current and E_r profiles determined using only the co-beam MSE channels with the same using co- plus counter-beam MSE channels. This comparison is meant to evaluate how well the improved spatial resolution and reduced B_z and E_r uncertainty in the new channels improve the accuracy of the reconstructed equilibrium. Special attention is paid to discharges designed to have high beta and bootstrap fraction. The expanded system is also capable of providing a direct measurement of $E_r$without relying on EFIT reconstruction. These measurements are presented and compared with those derived using the charge exchange recombination diagnostic.

[1]Supported by the US DOE under W-7405-ENG-48.

JP8.00090 Measurement and Modeling of the Response of the Current Profile Evolution to Feedback Control Actuators in DIII-D[1] , J.R. FERRON, P. GOHIL, C.M. GREENFIELD, T.C. LUCE, C.C. PETTY, P.A. POLITZER, GA, V. BASIUK, F. IMBEAUX, M. SCHNEIDER, CEA, T.A. CASPER, LLNL, M. MURAKAMI, ORNL, Y. OU, E. SCHUSTER, LeHigh U., Q. GAO, A. WANG, SWIP — For closed loop control of the q evolution during the plasma current ramp up, available actuators are electron heating power, I_p ramp rate, electron density and co-counter beam balance to modify the net neutral beam current drive. Measurements of the effects of these actuators on the current profile evolution are compared to transport code predictions from ONETWO, TRANSP, CRONOS, and CORSICA to test the model of the plasma response in the control process. Measurements of the dynamic response of the q evolution, particularly to electron heating, provide input to the controller development process. A proportional/integral controller with empirically determined gains and provision to avoid β_N excursions has been demonstrated to regulate q_{min} at the start of the high-performance phase of the discharge for a variety of initial and target conditions.

[1]Supported by the US DOE under DE-FC02-04ER54698, W-7405-ENG-48, DE-AC05-00OR22725, and DE-FG02-92ER54141.

JP8.00091 Development of Model-Based Feedback Control for the Current Profile in DIII-D[1] , Y. OU, C. XU, E. SCHUSTER, LeHigh U., T.C. LUCE, J.R. FERRON, M.L. WALKER, D.A. HUMPHREYS, GA, T.A. CASPER, W.H. MEYER, LLNL — A key goal in control of an advanced tokamak (AT) discharge is to maintain safety factor (q) and pressure profiles that are compatible with MHD stability at high beta and at high fraction of bootstrap current. This will enable high fusion gain and non-inductive sustainment of the plasma current for steady-state operation. Active feedback control of the q profile evolution at DIII-D has been already demonstrated [1], and an open-loop control scheme has been proposed [2]. We report up-to-date progress towards enabling model-based active control of the current profile during the plasma current ramp-up phase. New results on closed-loop control design, simulation assessment with Corsica, and initial open-loop-control experiments are presented. [1] J.R. Ferron, et al., Proc. 32nd EPS Conf. on Plasma Physics, vol. 29C (2005) 1069. [2] Y. Ou, et al., Proc. Am. Control Conf., New York (2007).

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), the NSF CAREER award program (ECCS-0645086), and the US DOE under DE-FG02-92ER54141, DE-FC02-04ER54698, and W-7405-ENG-48.

JP8.00092 Model-Based Design for Operational Plasma Shape Control in DIII-D[1] , M.L. WALKER, D.A. HUMPHREYS, J.A. LEUER, GA, B. XIAO, ASIPP, S.H. HAHN, NFRC, E. SCHUSTER, Y. OU, M. ALSARHEED, LeHigh, D. GATES, PPPL, T.A. CASPER, W.H. MEYER, LLNL — Formerly, tokamak plasma control emphasized empirical tuning of simple controllers during experimental operations. Now, physics-based tokamak plasma response models are maturing and increasingly used as the basis for control design. This is essential for controller development for devices under design or construction, and key to maximizing the physics productivity of limited experimental time in operating devices. We report on experience at DIII-D and other tokamaks with shape control algorithms developed using physics-based models. We also describe a large and growing collection of Matlab functions, collectively known as the Tokamak System (TokSys) Toolbox, which standardizes much of the process of development and validation of tokamak plasma response models. Such standardization enables rapid model development, validation, and control design for operating and planned devices. Application to control development for several devices is described.

[1]Supported by the US DOE under DE-FC02-04ER54698, DE-FG02-92ER54141, DE-AC02-76CH03073, and W-7405-ENG-48.

JP8.00093 ROM-Based Current Profile Control in DIII-D[1] , C. XU, LeHigh University, Y. OU, E. SCHUSTER, LeHigh U., T.C. LUCE, J.R. FERRON, M.L. WALKER, D.A. HUMPHREYS, General Atomics, T.A. CASPER, W.H. MEYER, LLNL — The evolution in time of the current profile in a tokamak is related to the evolution of the poloidal flux, which can be modeled in cylindrical coordinates using a partial differential equation (PDE) usually referred to as the magnetic diffusion equation. Based on the proper orthogonal decomposition (POD) method, we propose a reduced-order model (ROM) for the magnetic diffusion equation (represented by an ordinary differential equation (ODE) with constrained diffusivity-interior-boundary actuators). We use a receding-horizon control scheme based on the reduced-order magnetic diffusion model to design a suboptimal control law that matches as close as possible a desired current profile within a pre-specified interval of time. Simulation results demonstrate the efficiency of the proposed control strategy.

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), the NSF CAREER award program (ECCS-0645086), and the US DOE under DE-FG02-92ER54141, DE-FC02-04ER54698, and W-7405-ENG-48.

JP8.00094 EFIT 3D Reconstruction and Recent Developments[1] , L.L. LAO, M.S. CHU, H.E. ST. JOHN, E.J. STRAIT, A.D. TURNBULL, General Atomics, Q. REN, ASIPP, Y.M. JEON, ORISE, D. FLANNAGAN, U. Tulsa — Recent 3D extension of the EFIT equilibrium reconstruction code to model toroidally asymmetric effects due to error and externally applied perturbation magnetic fields and other developments are presented. The 3D extension is based on an expansion of the MHD equations. Other developments include a new computational structure based on Fortran 90/95 with a unified interface that can conveniently accommodate different tokamak devices and grid sizes, as well as a Python-based GUI. New computational links that allow easy integration with transport and stability physics modules to facilitate kinetic reconstruction and stability analysis are also being developed. A new more complete uncertainty matrix for magnetic diagnostics based on knowledge about their fabrication, installation, calibration, and operation has also been implemented into EFIT and tested. Reconstructions with the new magnetic uncertainty matrix yield results similar to those using the existing one but with more realistic fitting merit figures.

[1]Work supported by US DOE under DE-FC02-04ER54698, DE-FG03-95ER54309, and DE-AC05-76OR00033.

JP8.00095 Integration of MHD Stability and Transport to Model DIII-D Pedestal Physics and ELMs[1] , G. LI, ASIPP, L.L. LAO, P.B. SNYDER, H.E. ST. JOHN, M.S. CHU, R.J. GROEBNER, G.M. STAEBLER, J.E. KINSEY, GA, J.M. PARK, M. MURAKAMI, ORNL, J.M. JEON, ORISE, W. GUO, Q. REN, ASIPP — Improving the predictive capability to model the H-mode edge pedestal is one of the critical tasks for tokamaks and ITER. Typically transport equations are solved with boundary conditions imposed well inside the pedestal. To accurately model the pedestal region, it is necessary to couple an edge stability code like ELITE to a transport model that is valid in the pedestal region. Our recent efforts in this area to model DIII-D pedestal height and edge localized modes (ELMs) is presented including the development of a simplified ELM-crash model to relax the edge J and temperature profiles. The edge electron and ion transport coefficient are set to large values based on the shape of the unstable eigenfunction from ELITE, if the edge P' exceeds the stable limit. Without an edge relaxation model, the predicted edge J tends to significantly exceed the experimental values. The effects due to ELMs will be discussed.

[1]Work supported by US DOE under DE-FG03-95ER54309, DE-FC02-04ER54698, DE-AC05-00OR22725, and DE-AC05-76OR00033.

JP8.00096 Modeling of Momentum Transport in DIII-D Discharges Due to Magnetic Drags Induced by MHD Activities[1] , Q. REN, ASIPP, M. CHU, L.L. LAO, H.E. ST. JOHN, R.J. LA HAYE, GA, J.M. PARK, ORNL, J.M. JEON, ORISE, C. ZHANG, D. ZHOU, G. LI, ASIPP — Toroidal rotation and rotational shear provide many beneficial effects to stabilize MHD instabilities and suppress turbulence that are crucial for attainment of high beta and high confinement envisioned for tokamak and ITER high performance regimes. MHD activities such as RWMs can interact with the plasma and slow down the rotation by breaking the toroidal symmetry to induce a toroidal viscosity. Preliminary results using ONETWO transport code with a simple inductive motor model indicate that the resonant magnetic drag effect alone cannot fully describe the evolution of the rotation profile in DIII-D RWM discharges. In these simulations, only the effects due to the perturbed radial magnetic fields estimated from experimental measurements at the q=2 surface were considered. Non-resonant magnetic damping effects due to ripple and neoclassical viscosity are being implemented in ONETWO and likely play a role. The results will be presented.

[1]Work supported by US DOE under DE-FG03-95ER54309, DE-FC02-04ER54698, DE-AC05-00OR22725, and DE-AC05-76OR00033.

JP8.00097 Simulations of DIII-D Sawtooth Oscillations Using Theory-Based Transport and Sawtooth Models[1] , Y.M. JEON, ORISE, G. LI, Q. REN, W. GUO, ASIPP, L.L. LAO, H.E. ST. JOHN, M.S. CHU, R. PRATER, GA, J.M. PARK, ORNL — Development and validation of a predictive sawtooth model is an important research topic for present-day tokamaks and ITER. Analysis using ONETWO to model the DIII-D sawtooth behavior due to the interactions between FW and NBI fast ions, predicts the observed reduction in the axis safety factor q_0 due to current profile evolution. Preliminary analysis indicates that the predicted drops in q_0 within a sawtooth cycle follow closely the experimental values from the EFIT code using MSE data. In ONETWO simulations, the evolution of q_0 within a sawtooth period is modeled with neoclassical resistivity and the experimental density and temperature profiles in two neighboring giant sawtooth cycles. Initial analysis using the Kadomtsev sawtooth model indicates that the sawtooth crash can be qualitatively reproduced with an appropriately chosen triggering parameter. The Porcelli sawtooth model is being implemented into ONETWO to more comprehensively predict the sawtooth crash.

[1]Work supported by US DOE under DE-AC05-76OR00033, DE-FG03-95ER54309, DE-FC02-04ER54698, and DE-AC05-00OR226725.

JP8.00098 Transport, MHD, and Stability Investigations of a Proposed Fusion Development Facility (FDF) , H.E. ST. JOHN, L.L. LAO, C.M. GREENFIELD, R. PRATER, P.B. SNYDER, G.M. STAEBLER, V.S. CHAN, R.D. STAMBAUGH, General Atomics — Recent simulations of a compact next generation testing facility tokamak, FDF, indicates that favorable H-mode, AT-type operation with high boostrap current fractions, is possible. Our simulations assumed an *apriori* fixed, stable edge pressure stable and peeling-ballooning modes and favorably shaped but fixed density profiles. Heating and current drive was supplied by on and off axis ECH and low energy, 120 keV, beams directed near the plasma edge. The resulting rotation speed profile is highly sheared at the plasma edge. Under these conditions we were able to simulate a suite of internal transport barrier confined discharges using the GLF23 transport model with the ONETWO transport code. Ongoing work includes extending these simulations to include fixed boundary MHD calculations, density evolution and dynamic ELM control using the ELITE edge stability code. We present the results and methodology required to perform these simulations.
[1] R.E. Waltz, *et al.,* Phys. Plasma **4**, 2482 (1997).

JP8.00099 Modeling ITER and DIII-D Current Ramps for Startup Similarity Experiments[1] , T.A. CASPER, W.H. MEYER, L.D. PEARLSTEIN, LLNL, G.L. JACKSON, J.R. FERRON, A.W. HYATT, T.C. LUCE, T.W. PETRIE, W.P. WEST, General Atomics, M. MURAKAMI, ORNL, R.A. MOYER, D.L. RUDAKOV, UCLA — We have begun similarity experiments on DIII-D to validate ITER startup scenarios and to explore possible alternatives. The reference startup scenario for ITER specifies breakdown near the outer limiter with shape variations correlated with the current ramp to give constant q until X-point formation. This evolution differs from startup prescriptions for existing tokamaks. Corsica simulations of the ITER current ramp indicate that the prescribed l_i may be difficult to achieve. Corsica is used to simulate ITER similarity experiments on DIII-D to validate startup design models. Possible alternatives that maintain vertical stability and the possibility for higher safety factor, $q_{min}>1$, more conducive to advanced tokamak and hybrid modes will be explored. The simulations use free-boundary evolution coupled with radial transport to assess the shape evolution and vertical stability.

[1]Supported by the US DOE under W-7405-ENG-48, DE-FC02-04ER54698, DE-AC05-00OR22725, and DE-FG02-04ER54758.

JP8.00100 Feasibility Studies of Off-Axis Neutral Beam Current Drive in DIII-D[1] , M. MURAKAMI, J.M. PARK, ORNL, T.C. LUCE, H.E. ST. JOHN, M.R. WADE, General Atomics, T.A. CASPER, LLNL — The objective of off-axis neutral beam (NB) current drive (CD) is to supplement the off-axis electron cyclotron current drive for development of steady state, advanced tokamak scenarios. A modification being considered is to tilt the present neutral beam lines (BL) by raising the source end of the BL by ≈ 1.5 m. The driven current is calculated using the TRANSP and ONETWO/Nubeam Monte-Carlo codes taking into account finite orbit effects. When the beam is injected in the same direction as the toroidal field, a wide but localized off-axis CD (≈ 40 kA/MW at $\rho = 0.5$ with FWHM of 0.45) is calculated. The normalized CD efficiency ($\zeta = 0.22$) is comparable or somewhat better than electron cyclotron current drive. Sensitivities to fast ion diffusion and the use of the off-axis CD for scenarios with high steady-state performance in DIII-D will be discussed.

[1]Supported by the US DOE under DE-AC05-00OR22725, DE-FC02-04ER54698, and W-7405-ENG-48.

JP8.00101 Modulated Electron Cyclotron Current Drive for Control of the m/n=2/1 Neoclassical Tearing Mode in DIII-D[1] , A.S. WELANDER, General Atomics, AND THE DIII-D NTM CONTROL FOR ITER THRUST TEAM — The m/n=2/1 neoclassical tearing mode (NTM) is a helical island structure at q=2 in the magnetic field of a high beta tokamak plasma that can degrade confinement and lead to disruption. The DIII-D control system has previously suppressed this NTM by driving continuous-wave (cw) current at q=2 using localized electron cyclotron current drive (ECCD). The control system has now been upgraded to modulate the ECCD so that current is driven only when the island passes by the deposition point. This modulation is expected to increase the effectiveness of the ECCD, in particular when the deposition region is broad relative to the island width, as will be the case in ITER. Experiments using modulated ECCD with a broad profile relative to the island width have been performed in DIII-D to control the 2/1 NTM. Results of these experiments will be presented.

[1]Supported by the US DOE under DE-FC02-04ER54698.

JP8.00102 Status and Plans for the 110 GHz ECH/ECCD System on DIII-D[1] , J. LOHR, I.A. GORELOV, H.J. GRUNLOH, D. PONCE, General Atomics, M. CENGHER, ORISE — There are now 5 gyrotrons in operation on DIII-D, producing 4 MW at 110 GHz for pulse lengths which are limited administratively to 5 s. The efficiency of transmission from the gyrotrons to the tokamak is about 80%, resulting in over 3 MW injected power. A sixth gyrotron is being repaired and will begin operation when a high voltage power supply now under construction is available. Stress fractures of the collectors due to cyclic fatigue resulted in vacuum failures on three of the first group of gyrotrons in the installation. New algorithms and equipment for sweeping the electron beams in the collectors have reduced the peak power loading in the collectors to levels < 600 W/cm^2, which results in predicted lifetimes of 50,000 gyrotron pulses where the fatigue limit is now determined not by single pulse stress but by fatigue due to the 5 Hz sweeping of the electron beam. A new fast fault processing system based on FPGA technology is being commissioned.

[1]Supported by the US DOE under DE-FC02-04ER54698 and DE-AC05-76OR00033.

JP8.00103 Power Calibration for the Electron Cyclotron Heating System on DIII-D[1] , M. CENGHER, ORISE, J. LOHR, I.A. GORELOV, D. PONCE, General Atomics, K. KAJIWARA, JAEA — The generated rf power for each of the five gyrotrons in the DIII-D system is calculated based on calorimetry, using temperature and flow measurements from the gyrotron and waveguide system cooling circuits for the cavity, window, collector, matching optics unit (MOU) and dummy loads. Analysis of the data involves fitting the dissipated energy versus time curves and integration of the energy for each of the circuits. The cavity signal is used to calculate the total generated energy, using a previously determined relationship between cavity loading and rf production, with other cooling circuits as a check. The time dependence of the rf power is determined using a diode pickoff at the first miter bend in the transmission line normalized to the integrated calorimetry measurement. The MOU calorimetry response provides a direct measurement of the percentage of rf in the Gaussian mode and the efficiency of coupling the rf into the waveguide. The losses in each transmission line are taken into account to calculate the power transmitted to DIII-D.

[1]Supported by the US DOE under DE-AC05-76OR00033 and DE-FC02-04ER54698.

JP8.00104 Improved Measurements of Injected Electron Cyclotron Power in DIII-D[1] , I.A. GORELOV, J. LOHR, D. PONCE, General Atomics, M. CENGHER, ORISE, P.S. JOHNSON, Butler U. — Direct measurements of the rf power injected into the DIII-D tokamak from the ECH gyrotrons are being made using a high power dummy load at the tokamak. The measurements will permitt power monitors, which measure the rf leakage from well-aligned gaps in the vacuum waveguides near the tokamak, to be calibrated for various elliptical polarizations of the rf propagating in the HE_{11} waveguide mode. Using these measurements, correlations with calorimetric measurements of the gyrotron cooling circuits, the usual basis for rf power measurements in the system, will be made. Low power rf measurements and theoretical and experimental estimates of the transmission efficiencies of the individual components in the transmission lines will be compared with the direct measurements.

[1]Supported by the US DOE under DE-FC02-04ER54698 and DE-AC05-76OR00033.

JP8.00105 Threshold Wave Amplitude Required for Non-adiabatic Wave-Particle Interaction[1] , M. CHOI, V.S. CHAN, General Atomics, AND RF SCIDAC TEAM — Non-adiabatic interactions between wave and ion in radiofrequency heating have typically been modeled as a quasi-linear diffusive process in velocity space. It assumes strong decorrelation in the relative phase difference between wave and ion through successive kicks. Since decorrelation depends strongly on the combination of applied wave amplitude, wave frequency, the magnetic field inhomogeneity and the energy of resonant ion, this assumption may not always be valid. We extend the previous work on threshold wave amplitude [Whang, *et al.*, Nucl. Fusion **23**, 481 (1983)], which is only valid for the fundamental harmonic, using standard linear mapping theory, and obtain more generalized expressions for arbitrary harmonic number with finite $k_{||}$ and ion finite Larmor radius effects. Analytical results for the stochasticity onset will be compared with numerical results evaluated from the code ORBIT-RF. We apply this formula to elucidate the validity of quasilinear diffusion for C-Mod minority ion fundamental harmonic as well as DIII-D energetic beam ion high harmonic heating regimes.

[1]Supported by the US DOE under DE-FG03-95ER54309.

JP8.00106 Experimental Comparison of Fast Wave Absorption on Fast Ions at Fourth and Sixth Harmonics[1] , P.I. PINSKER, C.C. PETTY, General Atomics, W.W. HEIDBRINK, UC-Irvine, F.W. BAITY, ORNL, M. PORKOLAB, MIT — In recent DIII-D experiments, we have compared the absorption of fast waves (FWs) on injected deuterium beams at the fourth and sixth deuterium cyclotron harmonics. Direct electron absorption also plays an important part in the core absorption. Up to 2 MW of FW power at 90 MHz is compared with a similar level of 60 MHz power in low-density L-mode discharges at 2 T with 1–2 MW of deuterium beam injection at 80 keV. Changes in the neutron rate and in the central sawtooth behavior are correlated with the observed acceleration of the beam ions by the rf as measured by the D_α charge exchange recombination diagnostic. Results obtained with hydrogen beams in which second and third harmonic absorption at 60 MHz and 90 MHz are compared will be presented. Lower global absorption efficiency observed for higher cyclotron harmonics in this multiple-pass absorption regime is attributed to the effect of an edge loss that competes with the core absorption mechanisms.

[1]Supported by the US DOE under DE-FC02-04ER54698, SC-G903402, DE-AC05-00OR22725, and DE-FG02-90ER54084.

JP8.00107 Results of Pilot Run of Next-Generation Thomson Scattering Diagnostic on DIII-D[1] , D.M. PONCE, B.D. BRAY, T.M. DETERLY, C.-L. HSIEH, C. LIU, General Atomics — A new prototype polychromator assembly and data acquisition system has been deployed during plasma operations at DIII-D for electron temperature and density measurement. The new polychromator features detectors that incorporate 500 MHz bandwidth amplifiers (OPA656) with low input bias current and an overall gain of 360 and an integration and a sample-and-hold circuit to provide analog output into a data acquisition digitizer. It also incorporates a TEC cooling circuit to maintain the avalanche photo-diodes (APDs) at 17°C with a stability of $\pm 0.1^\circ$C in order to reduce the environmental noise and reduce temperature fluctuations. The data acquisition system is a D-TACQ DT100 system with a 96 channel 250 kSPS ACQ196CPCI board. The new system provides the flexibility to increase both spatial and time resolution by removing limitations imposed by the old CAMAC system. Calibration and discharge data, along with measured electron temperature and density, will be compared to the ones obtained with the existing system.

[1]Supported by the US DOE under DE-FC02-04ER54698.

JP8.00108 New Optics for the Soft X-ray Diagnostic on DIII-D[1] , M.J. LANCTOT, Columbia U., E.M. HOLLMANN, UCSD, R.K. FISHER, S. PIDCOE, D.A. TAUSSIG, General Atomics — The optics for the soft x-ray poloidal array on the DIII-D tokamak have been upgraded to include a new set of 64 photodiodes and an adjustable filter wheel. The wheel includes three titanium-coated diamond filters for measuring soft x-ray emission and two unfiltered settings for fast bolometry. We present the specifics of the design, including filter transmission functions, and techniques used to reduce pickup noise from nearby coils. Recent results from the revamped system will be analyzed with a focus toward categorizing MHD instabilities observed in DIII-D plasmas.

[1]Supported by the US DOE under DE-FG02-89ER53297, DE-FG02-04ER54758, DE-FC02-04ER54698, and a Fusion Energy Science Fellowship.

JP8.00109 Theoretical Progress on Runaway Electron Suppression by Massive Gas Injection[1] , P.B. PARKS, W. WU, General Atomics, E.M. HOLLMANN, UCSD — Development of techniques to mitigate the severity of emergency plasma termination/plasma disruptions is deemed one of the highest priorities for ITER. The current method of mitigation by massive gas injection (MGI) is not fully understood; whether MGI can achieve sufficient density to avoid avalanche runaway electron formation in the high toroidal electric field E_ϕ is presently uncertain. It will be shown why direct penetration of broad gas jets cannot happen: ablation pressure drag (or magnetic pressure imbalance) exerted over the frontal surface of the jet is too strong for usual jets. Evidence on DIII-D is that MHD processes, occurring predominately during the short thermal quench TQ phase, cause inward diffusion of gas jet ions "stuck" at the plasma edge. To explore this process we have developed a 1-D large-aspect-ratio circular flux surface code for the evolution of E_ϕ with radiation and transport cooling. We use resistive wall boundary conditions, and a 2D axisymmetric CFD code describes the heavily-fueled vacuum region and plasma boundary conditions.

[1]Supported by US DOE under DE-FG03-95ER54309, DE-FC02-04ER54698, and DE-FG02-04ER54758.

JP8.00110 Experiments With a 6-Valve Array for Massive Gas Injection for Disruption Mitigation in DIII-D[1]

T.C. JERNIGAN, L.R. BAYLOR, S.K. COMBS, ORNL, E.M. HOLLMANN, J.A. BOEDO, R.A. MOYER, D.L. RUDAKOV, J.H. YU, UCSD, T.E. EVANS, D.A. HUMPHREYS, P.B. PARKS, E.J. STRAIT, J.C. WESLEY, M.A. VAN ZEELAND, W.P. WEST, GA, D.G. WHYTE, MIT, M. BAKHTIARI, FIT — A 6-valve array was installed on the DIII-D to test massive gas injection for suppression of runaway electrons during disruptions. Previous experiments were limited by the peak flow rate from a single valve. Initial experiments show somewhat improved electron assimilation before the core thermal quench (TQ). Peak core mixing efficiencies of impurities injected into the vacuum vessel through the TQ are ∼10%-40%. Tests using up to 5 valves were done in H_2, He, and 98% H_2-2% Ar. These experiments injected as much gas before the TQ as previously obtained during the entire TQ/I_p decay. They also showed the importance of maintaining the gas flow during the I_p decay to maintain the density. Densities of up to 2×10^{21} m^{-3} were obtained (∼10% of the Rosenbluth density for runaway suppression), but it was still increasing with added valves.

[1]Supported by the US DOE under DE-AC05-00OR22725, DE-FG02-04ER54758, DE-FC02-04ER54698, and DE-FG02-04ER54762.

JP8.00111 Runaway Electron Modeling Using Radiation Emitted From Impurity Pellets Injected in DIII-D[1]

A.N. JAMES, E.M. HOLLMANN, G.R. TYNAN, UCSD, G.L. JACKSON, General Atomics — Energy and spatial distribution of runaway electrons generated during disruptions and fast shutdowns are important for understanding the formation, loss, and mitigation of runaway electrons to prevent catastrophic damage in future tokamaks like ITER and DEMO. Monte Carlo simulations were performed to investigate injection of impurity pellets during disruptions to diagnose runaways in DIII-D. Interaction of runaways with solid pellets, and of emitted γ-rays with the vessel walls and scintillators placed outside the walls, including photo-neutron, are simulated. Energy straggling of γs passing through the vessel walls significantly skews the measured γ energy distribution; the spatial distribution of radiation associated with relativistic bremsstrahlung is found to provide good energy information in the expected runaway energy of 1-20 MeV. Temporal radiation intensity variations after pellet injection can reveal information on the spatial distribution of runaways. A proposed diagnostic using an array of 10-20 scintillators, and preliminary tests, will be presented.

[1]Supported by US DOE DE-FG02-04ER54758 and DE-FC02-04ER54698.

JP8.00112 Experiments Toward Understanding Impurity Assimilation During Massive Gas Injection for Disruption Mitigation in DIII-D[1]

E.M. HOLLMANN, J.A. BOEDO, R.A. MOYER, D.L. RUDAKOV, J.H. YU, UCSD, T.C. JERNIGAN, ORNL, T.E. EVANS, D.A. HUMPHREYS, P.B. PARKS, E.J. STRAIT, J.C. WESLEY, W.P. WEST, GA, M. GROTH, H. SCOTT, LLNL, D.G. WHYTE, MIT — Impurity assimilation following massive gas injection (MGI) is desirable for collisional suppression of runaway electrons (RE). Experiments on the DIII-D tokamak have shown that impurity ions created at the plasma edge by MGI initially mix inward quite slowly toward the plasma core. When the associated cold front reaches the q=2 rational surface, impurity mixing is accelerated due to destabilization of low-order tearing modes, leading to the thermal quench (TQ). Average core mixing efficiencies of impurities injected into the vacuum vessel up through the TQ are of order 10%. Typically, RE suppression ratios $\gamma_{crit} = E_{crit}/E_{||} \approx 0.01$ are obtained using argon. Better suppression ratios $\gamma_{crit} \approx 0.06$ are obtained with low-Z (H_2 or He) injection and firing five MGI valves simultaneously.

[1]Supported by the US DOE under DE-FG02-07ER54917, DE-AC05-00OR22725, DE-FG02-04ER54758, DE-FC02-04ER54698, W-7405-ENG-48, DE-FG03-95ER54309, and DE-FG02-04ER54762.

JP8.00113 REVERSED FIELD PINCHES —

JP8.00114 Overview of MST Results and Plans[1]

J.A. GOETZ, University of Wisconsin - Madison and the Center for Magnetic Self Organization in Laboratory and Astrophysical Plasmas, MST TEAM — MST progress in producing well-confined high beta plasmas continues. In high current plasmas with improved confinement through current density profile control (transient), the electron temperature is increased to 2 keV and the ion temperature is increased (through reconnection heating) to 1 keV. With pellet injection plasma beta (volume averaged pressure/surface magnetic pressure) increases to 26%, beyond linear stability limits for pressure-driven tearing and Mercier instability. Physics results on ion heating (correlated with reconnection), particle transport from stochastic fields, high frequency turbulence, momentum transport from tearing modes, and two-fluid reconnection are also obtained. In preparation for finer current profile control, lower hybrid (LH) and electron Bernstein waves are injected at about 175 kW, with LH- produced hard x-rays observed. New major projects under development include 1 MW neutral beam injection for auxiliary power deposition, programmable control of the toroidal field and poloidal loop voltage, oscillating field current drive at increased power, and fast Thomson scattering for electron temperature fluctuation measurements.

[1]Work supported by USDoE and NSF

JP8.00115 High-β, improved confinement RFP plasmas at high density

M.D. WYMAN, B.E. CHAPMAN, A.F. ALMAGRI, J.K. ANDERSON, D.J. DEN HARTOG, F. EBRAHIMI, D.A. ENNIS, G. FIKSEL, S. GANGADHARA, J.A. GOETZ, R. O'CONNELL, S.P. OLIVA, S.C. PRAGER, J.A. REUSCH, J.S. SARFF, H.D. STEPHENS, UW-Madison, F. BONOMO, P. FRANZ, Consorzio RFX, D.L. BROWER, B.H. DENG, W.X. DING, T. YATES, UCLA, S.K. COMBS, C.R. FOUST, ORNL, D. CRAIG, Wheaton College — In MST discharges with improved confinement, pellet injection has quadrupled the density, with n_e reaching $4\times10^{19}m^{-3}$. The energy confinement time of these high density plasmas is comparable to that at low density, and β_{tot} now reaches 26%. This beta exceeds the Mercier limit for interchange stability, but as yet no indication of interchange is detected experimentally. Beta is also now high enough for global $m = 1$ tearing modes to be linearly unstable, with the instabilities being driven by the pressure gradient rather than the current gradient. Although a β limit has not yet been reached, both the $m = 1$ fluctuation levels and energy transport do increase modestly at high β, suggesting the possibility that beta may eventually be limited by pressure-driven tearing. Work supported by USDOE.

JP8.00116 Generation and confinement of hot ions and electrons in MST[1]

B.E. CHAPMAN, A.F. ALMAGRI, J.K. ANDERSON, K. CASPARY, D.J. CLAYTON, D.J. DEN HARTOG, D.A. ENNIS, G. FIKSEL, S. GANGADHARA, J. GOETZ, R. O'CONNELL, R.M. MAGEE, S.C. PRAGER, J.A. REUSCH, J.S. SARFF, H.D. STEPHENS, University of Wisconsin-Madison, F. BONOMO, P. FRANZ, Consorzio RFX, D.L. BROWER, B. DENG, W.X. DING, T. YATES, University of California, Los Angeles, D. CRAIG, Wheaton College — During impulsive magnetic tearing and reconnection in MST, many MW of ion heating power are derived from the energy stored in the magnetic field, causing T_i to jump well above 1 keV. By subsequently and quickly suppressing the reconnection, ion energy confinement is improved at least ten-fold, and T_i above 1 keV is retained in the plasma. During the period of reconnection suppression, electron energy confinement is also improved, and the ohmically-heated electrons reach a temperature approaching 2 keV. Impulsive reconnection is a common feature of MST plasmas, driven by peaking of the current profile, but in this work, the reconnection and conversion of magnetic energy is intensified. Reconnection suppression is achieved with the now-standard PPCD technique, wherein parallel current is inductively driven to flatten the current profile.

[1]Supported by USDOE and NSF.

JP8.00117 Fast Ion Generation in the MST[1] , RICHARD MAGEE, BRETT CHAPMAN, DAVID ENNIS, GENNADY FIKSEL, ROB O'CONNELL, University of Wisconsin - Madison, MADISON SYMMETRIC TORUS TEAM, CENTER FOR MAGNETIC SELF-ORGANIZATION COLLABORATION — Reversed-field pinch plasmas in the MST are punctuated by bursts of tearing mode activity, which release energy stored in the magnetic field and strongly heat the ions. There are two indications that some of these reconnection events generate a population of suprathermal ions. The first is that the neutron flux from the plasma tends to be higher than that expected from thermal fusion based on the measured impurity temperature. Because the D-D fusion cross section is much larger for higher energy ions, a small, fast population can resolve this discrepancy. The second is that fast, charge exchange neutrals are sometimes observed in a neutral particle energy analyzer. An attempt to experimentally reconstruct the energy spectrum of these particles will be described. One hypothesis for these observations is that a mean electric field associated with current profile relaxation is creating runaway ions. To investigate, computational work has been done to determine the implied ion distribution function and the conditions necessary to produce it.

[1]Work supported by US DoE and NSF

JP8.00118 Fokker-Planck modeling of 2 keV Thomson Scattering electron temperature measurements on the MST.[1] , R. O'CONNELL, D.J. DEN HARTOG, B.E. CHAPMAN, C.B. FOREST, J.A. REUSCH, H.D. STEPHENS, University of Wisconsin - Madison, M.T. BORCHARDT, R.W. HARVEY, CompX, Del Mar, CA., MST TEAM — On the MST RFP some 2 keV high confinement plasmas display an off-axis peak in the electron temperature profile measured by the Thomson scattering diagnostic. The distribution function computed by the Fokker-Planck modeling code CQL3D is used to predict the spectral distribution of the scattered radiation from a Nd:YAG laser pulse. The off- axis peak in the temperature profile may be explained by a distortion of the electron distribution in the parallel direction, caused by the high parallel electric field in the plasma. This distortion of the parallel distribution function influences primarily the off-axis scattered spectral distribution; on axis, the Thomson scattering diagnostic is sensitive only to the perpendicular electron distribution. The signal-to-noise ratio of the data is insufficient to allow direct inversion to an electron distribution function, so comparison to Fokker-Planck modeling predictions is key to understanding unusual features in the temperature profile and spectral distribution.

[1]This work is supported by the U. S. Department of Energy.

JP8.00119 High Time Resolution Analysis of Thermal Transport and Magnetic Stochasticity During a Sawtooth Event in MST[1] , J.A. REUSCH, J.K. ANDERSON, F. EBRAHIMI, A.F. FALKOWSKI, D.J. DEN HARTOG, C.B. FOREST, R. O'CONNELL, H.D. STEPHENS, University of Wisconsin - Madison — New measurements with the multi-point, multi-pulse, Thomson scattering system on MST have enabled the analysis of the radial thermal diffusion (χ_e) profile within tens of microseconds of magnetic reconnection events known as sawteeth. Diffusion of thermal energy out of the plasma along stochastic magnetic field lines is believed to be the major mechanism of heat loss during these magnetic relaxation events. At the sawtooth crash the magnetic fluctuations are large and the magnetic field becomes fully stochastic throughout much of the plasma volume. By ensembling data from many similar shots, we have determined the evolution of the χ_e profile through the sawtooth crash with much higher time resolution than was previously possible. These new measurements cover the critical half millisecond around the sawtooth crash with 50μs wide bins. The evolution of the χ_e profile obtained from experiment is compared to Rechester-Rosenbluth predictions and results of MHD simulations done with the DEBS code.

[1]Work supported by the U.S. DOE.

JP8.00120 Electron temperature fluctuation measurements using a two-pulse Thomson scattering diagnostic on MST , H.D. STEPHENS, A.F. FALKOWSKI, D.J. DEN HARTOG, R. O'CONNELL, J.A. REUSCH, University of Wisconsin - Madison — Advanced Thomson scattering diagnostic capabilities enable exploration of fast electron dynamics that may be associated with several physical processes such as tearing modes, dynamo mechanisms and electrostatic fluctuations. The photon sources for the Thomson scattering diagnostic on MST are two independently triggerable Nd:YAG lasers. The two lasers can be fired arbitrarily close together in time. Data acquisition becomes the limiting factor in time resolution. Overall the system is capable of measuring changes in the radial electron temperature profile with a temporal resolution of 200 ns and with a spatial resolution of 2 cm or less. A fluctuation power spectrum can be built up over an ensemble of shots. The power spectrum of electron temperature fluctuations near tearing mode frequencies (5-30 kHz) is presented as well as a correlation analysis of temperature and magnetic modes. How this method can be applied to higher frequency fluctuations is discussed. The research was performed under appointment to the Fusion Energy Sciences Fellowship Program and supported by US DOE.

JP8.00121 Construction of a Pulse-Burst Laser System for Fast Thomson Scattering on the MST RFP[1] , D.J. DEN HARTOG, University of Wisconsin-Madison and Center for Magnetic Self-Organization — A "pulse-burst" laser system is being constructed for addition to the Thomson scattering diagnostic on the MST RFP. This laser will produce a burst of up to 200 approximately 1 J Q-switched pulses at repetition frequencies 5-250 kHz. This laser system will operate at 1064 nm and is a master oscillator, power amplifier (MOPA). The master oscillator is a compact diode-pumped vanadate laser, intermediate amplifier stages are flashlamp-pumped Nd:YAG, and final stage(s) will be flashlamp-pumped Nd:glass (silicate). The burst train of laser pulses will enable the study of Te and ne dynamics in a single MST shot, and with ensembling, will enable correlation of Te and ne fluctuations with other fluctuating quantities.

[1]This work is supported by the U. S. Department of Energy and the National Science Foundation.

JP8.00122 Dynamic Heavy Ion Beam Probe Measurements in the Madison Symmetric Torus[1] , D.R. DEMERS, X. CHEN, K.A. CONNOR, P.M. SCHOCH, Rensselaer Polytechnic Institute, S.Y. ZHANG, University of Wisconsin - Madison — The Heavy Ion Beam Probe in operation on the Madison Symmetric Torus is now utilizing two new diagnostic features. The first is a programmable computerized control system which is enabling measurements in plasmas with gradual, deliberate equilibrium variations such as those which occur during improved confinement discharges. The system tracks dynamic equilibria using tailored temporal adjustments of the sweep and analyzer voltages; the primary goal of the system is to enable continuous measurements and the secondary goal is to maintain fixed sample volume locations. The second new diagnostic feature is an aperture which facilitates inference of the secondary beam position and velocity. This information, combined with the velocity and location of the primary ion beam as it enters the plasma, is useful as a constraint for magnetic equilibrium reconstruction. The accuracy of magnetic equilibria impacts HIBP sample volume localization, size, and orientation calculations, which in turn effect electric field and wavenumber measurements. Data acquired with, and overviews of the computerized control system and beam velocity aperture will be presented.

[1]This work is supported by USDoE.

JP8.00123 Time-resolved measurements of equilibrium profiles in MST[1] , B.H. DENG, D.L. BROWER, W.X. DING, T.F. YATES, UCLA, J.K. ANDERSON, K. CASPARY, K.J. MCCOLLAM, S.C. PRAGER, J.A. REUSCH, J.S. SARFF, UW Madison, D. CRAIG, Wheaton College — Based on the high-speed, three-wave, far-infrared polarimeter-interferometer measurement of B_{pol} profiles and external coil measurements of B_{tave} and B_{tw}, a new method is developed to derive B_{tor} and other equilibrium profiles ($J_{//}$ and q) with high time resolution. Using Faraday's law, the inductive electric field ($E_{//}$) profile is also deduced from the temporal derivatives of the time-resolved magnetic field profiles. The derived $B(0)$ values have excellent agreement with direct measurements using a Motional Stark Effect (MSE) diagnostic. Evolution of equilibrium profiles during single sawtooth events in MST, both the slow linear ramp and crash phases, are presented. Profile scaling with plasma current I_p and reversal parameter F is also explored. MHD stability is tested from the spatial gradients of the $J_{//}$ and q profiles, and correlation with fluctuation mode amplitude is investigated. Future improvements to equilibrium reconstruction are expected by measuring B_{tor}(r,t) directly via Cotton-Mouton interferometry.

[1]Work supported by US DoE.

JP8.00124 Locally Improved Particle Confinement in QSH Plasmas , D.J. CLAYTON, B.E. CHAPMAN, R. O'CONNELL, D.R. BURKE, J.A. GOETZ, M.C. KAUFMAN, UW-Madison, F. BONOMO, M. GOBBIN, L. MARRELLI, P. MARTIN, P. PIOVESAN, Consorzio RFX — A multichord array of CdZnTe detectors is used on MST to infer electron particle diffusion in improved confinement plasmas by measuring hard-x-ray (HXR) flux emitted by runaway electrons. In quasi-single-helicity (QSH) plasmas, where one mode dominates the core tearing mode spectrum and forms an island on its resonant surface, we expect closed flux surfaces to appear inside the island and improve confinement. HXRs are observed when an island emerges, as detected by a SXR diagnostic and the HXR flux oscillates in phase with the rotation of this island. While HXR energies measured during QSH reach those of improved confinement, pulsed parallel current drive (PPCD) plasmas, other diagnostics show a smaller improvement in global confinement, indicating that regions of improved confinement are localized. Modeling with the ORBIT code shows that runaway electrons are better confined inside the island than in the exterior stochastic region. Work supported by the USDOE.

JP8.00125 X-ray emission maps in the MST reversed field pinch , P. FRANZ, F. BONOMO, G. SPIZZO, Consorzio RFX - Padova, Italy, B.E. CHAPMAN, J.A. GOETZ, University of Wisconsin - Madison — We present two-dimensional images of the soft x-ray (SXR) emissivity distributions in the core of the MST reversed field pinch plasma. The measurements have been obtained with the SXR tomographic diagnostic comprised of four cameras (each with a multichannel photodiode array) viewing the plasma at different poloidal angles, with a total of 74 channels. An overview of results obtained in enhanced confinement plasmas (PPCD experiments) will be shown. Individual islands and helical structures can be resolved by the high spatial resolution of the diagnostic, and their time evolution can be followed thanks to the high time resolution of the electronics. The measurements have been performed exploring various SXR energy ranges by alternatively changing the beryllium foils thicknesses in the photocameras. Examples of SXR distributions with the same filter thickness in all the four probes will be presented and will be analyzed together with those measured with different foils for each camera. When the SXR emissivity is measured with only two filters in the same shot a 2-D estimate of the electron temperature in the plasma core can be obtained by using the standard two-foil technique. Some initial results on T_e calculations will be shown.

JP8.00126 Tearing Mode Flow Measurements in MST , D. A. ENNIS, S. GANGADHARA, D.J. DEN HARTOG, G. FIKSEL, F. EBRAHIMI, V.V. MIRNOV, S.C. PRAGER, University of Wisconsin-Madison and the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, D. CRAIG, Wheaton College — Fluctuating flows driven by resistive tearing modes are observed in a number of laboratory and astrophysical plasmas, including the MST reversed field pinch. Carbon emission from neutral beam-induced charge exchange recombination is collected by a custom-built, high throughput spectrometer yielding measurements of carbon impurity ion velocity localized to $+/-$ 1 cm with high bandwidth (100 kHz). We have measured the correlation between poloidal velocity fluctuations and magnetic fluctuations associated with tearing modes resonant across the plasma radius providing correlated flow fluctuations resolved to better than 500 m/s. Strong correlations are observed for a range of $m = 1$ magnetic modes, and the measurements are consistent with tearing mode flows parallel to the mean magnetic field. Correlations are largest near the tearing mode resonant surfaces, and are narrow in space, in contrast to the broad structure of magnetic fluctuations. However, flow fluctuations associated with the dominant mode broaden during quasi-single-helicity plasmas. Theoretical calculations and computational modeling of linear and nonlinear tearing mode flows have been performed, and comparisons with the experimental results will be presented. Work supported by USDoE and NSF.

JP8.00127 Hall dynamo, charge transport, and plasma rotation due to magnetic fluctuations in the MST RFP , A. KURITSYN, G. FIKSEL, A.F. ALMAGRI, T.D. THARP, Center for Magnetic Self-Organization, Department of Physics, University of Wisconsin-Madison — Standard discharges in the Madison Symmetric Torus (MST) Reversed-Field Pinch (RFP) are characterized by cyclical rapid relaxation events (sawteeth), when substantial toroidal magnetic flux is generated in the plasma edge. In the framework of the two-fluid Ohm's law, it can be shown that Hall and MHD dynamo mechanisms play an important role. We will present detailed measurements of the radial profile of the Hall dynamo $\left\langle \tilde{\mathbf{j}} \times \tilde{\mathbf{B}} \right\rangle_{||}$ in the edge. These measurements were performed with a newly developed magnetic probe, which combines six magnetic coil triplets. Hall dynamo is peaked at the reversal surface, but is reduced near the edge, where, according to the past measurements, it is replaced by the MHD dynamo. We will also report edge measurements of the fluctuation induced non-linear $\left\langle \tilde{j}_{||} \tilde{B}_r \right\rangle_{F.S.}$ term, which is expected to play an important role in governing charge and particle transport, as well as to be significant in providing torques, which cause intrinsic (without external momentum input) plasma rotation. In addition, we will discuss experiments on inducing plasma rotation with bias electrodes inserted into the plasma edge. This work is jointly supported by the U.S. DOE and NSF.

JP8.00128 Edge Measurements of Plasma Momentum Dynamics in MST[1] , M.C. MILLER, A.F. ALMAGRI, D. CRAIG, D.A. ENNIS, G. FIKSEL, S. GANGADHARA, A. KURITSYN, S.C. PRAGER, T.D. THARP, University of Wisconsin - Madison and the CMSO — In the MST reversed field pinch, the dynamics of plasma momentum during reconnection are governed by two fluctuation induced nonlinear terms: the Reynolds stress, $\rho(\widetilde{\mathbf{v}} \cdot \nabla)\widetilde{\mathbf{v}}$, and the Maxwell stress, $\widetilde{\mathbf{j}} \times \widetilde{\mathbf{B}}$. Previous measurements in both the edge and core plasma show the Maxwell stress to be about 10 times larger than either the inertial or the viscous term in the momentum balance equation. Recently, measurements of the Reynolds stress have been performed in the edge plasma of MST using probes. A spectroscopic probe looking at He II line emission is used to measure radial velocity fluctuations, and a Mach probe is used to measure the toroidal and poloidal velocities. The Reynolds stress, as reconstructed from these measurements, is shown to balance the Maxwell stress in the edge and both are an order of magnitude larger than the inertia, thus indicating that these two stresses dominate edge plasma dynamics during reconnection.

[1]This work is supported by the NSF and the US DOE

JP8.00129 Measurements of Linear and Nonlinear Hall Reconnection[1] , T.D. THARP, A.F. ALMAGRI, D. CRAIG, G. FIKSEL, A.V. KURITSYN, M.C. MILLER, V.V. MIRNOV, S.C. PRAGER, J.S. SARFF, MST and CMSO at the University of Wisconsin-Madison — Previous measurements in MST have established that two-fluid Hall effects produce a dynamo during sawtooth relaxation events, and therefore two-fluid dynamics are important when evaluating the macroscopic effects of reconnection. This was established by measuring the nonlinear Hall term $(J_1 \times B_1)$ in the axisymmetric (flux-surface averaged) Ohm's Law. Here, we report measurements of terms in the non-axisymmetric Ohm's Law, including the *linear* Hall term, $(J_1 \times B_0 + J_0 \times B_1)$, and other spatially varying quantities. These measurements are a more direct indicator of the role of two-fluid effects on reconnection. Measurements are performed by probes in the vicinity of the reversal surface to measure reconnection associated with modes of poloidal mode number m=0. Results show that the linear Hall term is large compared to $\eta \widetilde{J}_{||}$, indicating the possibility of fast collisionless reconnection. Results are compared to a theoretical interpretation based on two-fluid MHD.

[1]Work supported by US DOE and NSF.

JP8.00130 Measurements of core density and magnetic field fluctuations on the MST[1] , TRAVIS YATES, WEIXING DING, TROY CARTER, DAVID BROWER, UCLA, JOHN SARFF, STEWART PRAGER, University of Wisconsin, Madison — Fluctuations play an important role in anomalous particle, momentum and energy transport. Core magnetic and density fluctuations are measured using a high-speed, laser-based, Faraday rotation-interferometry system with a bandwidth of 500 kHz and 8 cm chord spacing. Line-averaged measurements of magnetic and density fluctuations can be inverted using a newly developed inversion method to obtain the local spatial profiles. Spatial structure for modes with m=1, n=6 up to n=16, as well as the m=0, n=1 mode are identified. Fluctuation profiles for modes of given helicity show noticeable changes during the sawtooth cycle. These measurements can also be exploited to determine the local plasma displacement ($\xi_r = \delta n/\nabla n_0$) and radial velocity fluctuations ($\tilde{v}_r = \partial\xi_r/\partial t$) associated with stochastic magnetic fields. Using these parameters, issues related to anomalous particle and momentum transport are addressed. Detailed modeling of local particle density and magnetic fluctuations will be presented.

[1]Work supported by U.S. Department Of Energy.

JP8.00131 Measurements of High Frequency Magnetic Fluctuations in MST[1] , Y. REN, A.F. ALMAGRI, G. FIKSEL, S.C. PRAGER, J.S. SARFF, UW-Madison, CMSO — Reversed field pinch plasmas are rich in magnetic fluctuations, dominated by low frequency tearing modes (∼10-30 KHz) which play important roles in magnetic self-organization and transport. However, the origin of high frequency fluctuations (>100 KHz) remains unclear. The increase of high frequency fluctuation power during fast reconnection events (sawteeth) suggests that magnetic energy may cascade from the tearing modes to the high frequency fluctuations. Here we present detailed measurements of edge magnetic fluctuations in MST using an insertable magnetic probe, where the toroidal and poloidal mode numbers, n and m, were obtained using the two- point correlation method. The radial dependence of the fluctuation characteristics (power spectra, dispersion relations, etc.) was quantified. The time evolution of the fluctuations during the sawtooth cycle is also resolved. Interestingly, at the sawtooth crash the high frequency fluctuations (∼200-400 KHz) become almost parallel- propagating relative to the equilibrium field, and the phase velocity is close to the ion thermal velocity. This suggests that these high frequency fluctuations may be magnetosonic waves, expected to be strongly damped to produce strong ion heating.

[1]Work supported by USDoE and NSF

JP8.00132 Lower Hybrid Current Drive Experiments on MST[1] , M.C. KAUFMAN, J.A. GOETZ, D.R. BURKE, A.F. ALMAGRI, University of Wisconsin, Madison — Lower hybrid current drive has been offered as a means to reduce tearing fluctuations and improve confinement in the reversed field pinch. The third generation interdigital-line antenna has been installed in MST and preliminary testing has been completed. Source power to the antenna has been increased to >220kW in both feed directions. At high power, the $n_{\|}$ spectrum has been measured and is peaked at ~ 7.5 as expected with excellent directionality. Hard x-ray bremsstrahlung emission from rf-generated fast electrons with energies up to and beyond 60 keV has been observed using CdZnTe detectors. Emission in the co-current drive direction is toroidally localized in the plane of the antenna while the counter-current drive direction produces an order of magnitude less flux and peaks off-plane of the antenna. It is surmised that this localization results from diffusion of fast electrons away from a local current structure created by launch into low-confinement plasmas. Collimated x-ray emission profiles near the antenna will also be presented.

[1]Work supported by US DOE Contract DE-FC02-05ER54814

JP8.00133 Diagnosis and Modeling of the Lower Hybrid Wave Injection on MST[1] , DAVID BURKE, JOHN GOETZ, MICHAEL KAUFMAN, ABDULGADER ALMAGRI, JAY ANDERSON, STEWART PRAGER, University of Wisconsin Madison, JOHAN CARLSSON, Tech-X Corperation, TECH-X CORPERATION COLLABORATION — RF current drive is predicted to reduce tearing fluctuations in reversed field pinches. Lower hybrid experiments with coupled power up to 125 kW have been undertaken on the Madison Symmetric Torus. The lower hybrid antenna exhibits good coupling under a variety of plasma conditions. Experimental studies have been undertaken to determine the optimal conditions for antenna operation. Additionally, an effort is underway to model plasma loading and launch spectrum using AORSA and RANT. Thirteen CdZnTe detectors are used in conjunction with a 16-channel CdZnTe camera in order to diagnose lower hybrid discharges. X-rays with energies over 60 keV are detected during such discharges. This x-ray emission is observed to be toroidally localized to the area within 60° of the lower hybrid antenna. The spectrum also shows a dependence on launch direction. In order to expand our understanding of these results, several different plasmas have been modeled with GENRAY and CQL3D. Experimental results with source power up to 200 kW and current modeling results will be presented.

[1]Work supported by US DOE Contract DE-FC02-05ER54814

JP8.00134 EBW Injection Experiment in the MST , JAY K. ANDERSON, WILLIAM COX, CARY FOREST, University of Wisconsin-Madison — A 0.25 MW system designed to heat electrons and drive current via the electron Bernstein wave is in its early stages of operation on the MST reversed field pinch. The antenna is a grill of four half-height S-band waveguides with each arm powered by a separate, phase controlled traveling wave tube amplifier. Coupling to the plasma (as measured by ratio of reflected power) is very dependent on the relative phasing between adjacent waveguides. The total reflected power can be maintained at or below 25%, similar to that measured for a two-waveguide full height grill [1]. The antenna face is outfitted with a pair of triple Langmuir probes to measure local electron density; the density gradient at the upper hybrid resonance (typically within 1-2 cm of the antenna) is expected to strongly influence coupling efficiency. Conditioning of the antenna is currently underway (near the 0.2MW level) and total system power is expected to reach 0.25MW, or roughly a fourth of the Ohmic input power in target plasmas. The x-ray spectrum (5-200 keV) is monitored as a way to detect modification to the electron distribution as full transmitter power is approached. This work is supported by USDOE.
[1] M. Cengher, J. K. Anderson, C. B. Forest, V. Svidzinski, *Nuc Fusion* **40**, 521 (2006).

JP8.00135 Fokker-Planck Modeling of X-ray Emission Due to Electron Bernstein Wave Heating in MST , W.A. COX, J.K. ANDERSON, C.B. FOREST, R. O'CONNELL, University of Wisconsin - Madison, MADISON SYMMETRIC TORUS TEAM — Experiments on MST are underway to test the viability of using electron Bernstein waves (EBW) to heat and drive current in the reversed field pinch. This proof-of-principle experiment uses 250 kW of rf power at 3.6 GHz, a power level that is typically much lower than the Ohmic input power in MST. Power coupling experiments show that power launched into the plasma chamber exceeds 120 kW; the response of various diagnostics to this EBW power is modeled for comparison with experiment using GENRAY ray-tracing and CQL3D Fokker-Planck codes. This procedure inhibits variation of the current profile from equilibrium and allows the inductive electric field to respond on short time scales to maintain a constant current density. CQL3D then predicts the x-ray fluxes and Thomson scattering signals corresponding to the modified electron distribution, which are compared to experimental data. Initial modeling results indicate that the main response can be interpreted as electron heating and that non-thermal features in the distribution function are difficult to detect using x-ray diagnostics. This work is supported by the United States Department of Energy.

JP8.00136 High Power Neutral Beam Injection System for the MST[1] , G. FIKSEL, A.F. ALMAGRI, B.E. CHAPMAN, D.J. DEN HARTOG, S.P. OLIVA, S.C. PRAGER, J.S. SARFF, UW-Madison, A.A. IVANOV, G.F. ABDRASHITOV, V.I. DAVYDENKO, P.P. DEICHULI, V.V. KOLMOGOROV, V.V. MISHAGIN, A.V. SORKOKIN, N.V. STUPISHIN, BINP, Novosibirk, Russia — Good fast ion confinement in the RFP plasma has been established for some time. Currently, a high power neutral beam injection system for the MST reversed field pinch is being designed and built. The hydrogen neutral beam will have power of 1MW, energy of 25 keV, and duration of 20 ms. Among the goals of the beam injection experiment are: (a) to investigate the beam energy and momentum deposition into the plasma, (b) to study the effect of the fast particles pressure (beta) on plasma confinement, and (c) to study the effect of the fast particles on the tearing and kinetic instabilities in the MST. The injection system details and modeling of the beam-plasma interaction will be presented

[1]Work supported by USDoE

JP8.00137 Energy and Helicity Balance in Oscillating Field Current Drive Experiments[1] , K.J. MCCOLLAM, F. EBRAHIMI, J.S. SARFF, D.R. STONE, A.F. ALMAGRI, J.K. ANDERSON, D.J. DEN HARTOG, G. FIKSEL, R. O'CONNELL, S.C. PRAGER, UW-Madison, D.L. BROWER, B.H. DENG, W.X. DING, UCLA, D. CRAIG, Wheaton College — Oscillating field current drive (OFCD) is a proposed method of efficient, steady-state toroidal plasma current sustainment using AC poloidal and toroidal loop voltages. OFCD is added to a standard RFP in the MST device, increasing the net plasma current by ∼10%. Magnetic fluctuations are modulated by the OFCD cycle, affecting energy and helicity balance. While the central electron pressure oscillation is large (∼50% amplitude), the total beta ($=2\mu_0 <p_e+p_i>/B^2(a)$) oscillation is smaller, and the cycle-average beta (∼7%) is about the same as the standard RFP case without OFCD. The energy confinement time also oscillates with a cycle-average (∼1 ms) about the same as the standard case. The measured helicity content is nearly equal to the measured injection minus the measured equilibrium dissipation. The residual may be coherent with the modulated MHD activity, implying some fluctuation-induced helicity dissipation, which will be measured in future tests. The experimental results are generally consistent with 3D resistive-MHD simulations.

[1]This work is supported by the US DOE.

JP8.00138 Upgraded Oscillating Field Current Drive on MST , D.R. STONE, K.J. MCCOLLAM, P.D. NONN, J.S. SARFF, S.C. PRAGER, University of Wisconsin - Madison — The oscillating field current drive (OFCD) system for MST has been upgraded for higher power capability to investigate larger current drive. In OFCD, two frequency-matched ac magnetic fields are inductively applied to the plasma, one in the poloidal direction and the other in the toroidal direction. The fields interact to inject net magnetic helicity into the plasma depending on their phase difference, thereby driving a toroidal current. The basic design of the OFCD system remains the same: two pre-charged LC tank circuits inductively couple to MST's main magnet circuits. The upgraded tank circuits operate at double the previous voltage and are more strongly coupled to the main circuits, both of which allow more input power into the plasma. So far, the input power at the phase which produces the maximum plasma current has been increased to about 400 kW compared to 200 kW with the previous system. Larger current drive by OFCD is observed (>10% increase over the baseline current at low current). However, magnetic fluctuations due to the unavoidably larger equilibrium modulation and/or plasma-wall interaction appear to be more important as limiting factors at these higher power levels. Tests at larger baseline current are underway. This work was supported by the US DOE.

JP8.00139 A new hybrid inductive scenario for a nearly steady-state Reversed Field Pinch[1] , J.S. SARFF, University of Wisconsin-Madison — Steady-state current sustainment is challenging for the Reversed Field Pinch (RFP). The current magnitude is large, while the pressure-driven (bootstrap) current is small, even at the RFP's high beta >20%. In the TITAN (RFP) system study [1], the current was designed steady-state using Oscillating Field Current Drive (OFCD), i.e., steady magnetic helicity injection using phased AC induction. Experiments and theory for OFCD are so far promising, but OFCD's reliance on magnetic relaxation could turn out incompatible with energy confinement requirements. Meanwhile inductive current profile control has demonstrated tokamak-like confinement in the RFP. Such control is inherently not steady-state. A hybrid scheme is proposed using OFCD to ramp the current, followed by a pulsed-burn during which inductive profile control maintains high confinement. The current is not constant but never goes to zero (sawtooth-like waveform). The current drive (and profile control) is efficient induction, simply applied at the plasma surface. The pulsed-burn phases could be separated by only a few seconds. Optimization of the hybrid cycle and other issues will be discussed.

[1] http://aries.ucsd.edu/LIB/REPORT/TITAN/final.shtml

[1]Work supported by the U.S. DoE.

JP8.00140 Numerical Simulation of Pulsed Parallel Current Drive in RFPs[1] , J.M. REYNOLDS, Los Alamos National Laboratory, C.R. SOVINEC, S.C. PRAGER, University of Wisconsin-Madison — The effects of applying inductive electric field pulses to saturated reversed-field pinch states are investigated numerically with the NIMROD code [1]. Simulation diagnostics are used to measure power transfer among groups of harmonics, and the instantaneous free energy in the mean fields is assessed with linear analysis techniques. The most effective technique in the Madison Symmetric Torus applies pulses of poloidal electric field while simultaneously reducing the loop voltage. Nonlinear simulations show that the initial response is an increase in edge parallel current that promptly decreases power transfer from the mean fields to core- and edge-resonant helical fluctuations. Linear analysis finds a consistent trend toward stabilization for these harmonics. The normal nonlinear balance is altered, reducing the power to nonlinearly sustained m=0 modes and decreasing the overall fluctuation level. Reducing loop voltage is shown to have little effect initially, but it keeps the mean profile from evolving to a more pinched and unstable configuration.

[1] Sovinec et al., JCP 195, 355 (2004).
[2] Chapman et al., PoP 9, 2061 (2002).

[1]Supported by the US DOE.

JP8.00141 Features of ITG Modes in the RFP

, VARUN TANGRI, P.W. TERRY, University of Wisconsin-Madison, R.E. WALTZ, General Atomics, San Diego — Global tearing modes, which normally dominate core transport in the RFP, are largely stabilized when the current profile is externally controlled. This allows small-scale modes to become a significant factor in RFP confinement, both global confinement and edge particle confinement. The driving source of the small-scale modes observed in the RFP has never been determined. Drift modes, resistive g-modes, and rippling modes are too weak in the strong magnetic shear to explain observations. We examine here the linear stability of the ion temperature gradient mode, Using GYRO [1] in a low beta, collisionless limit, linear gyrokinetic simulations in real toroidal RFP geometry have been performed. To benchmark and assess the results we make comparisons with fluid theory and prior calculations. To determine the nature of the instability we study parametric scalings and mode structure. We evaluate growth rates for MST parameters, and using mixing length arguments, determine if the instability is relevant to the small-scale turbulence observed in MST. [1] J. Candy and R.E. Waltz, J. Comp. Phys. 186, 545 (2003).

JP8.00142 Magnetic Fluctuation Spectrum in the RFP

, P.W. TERRY, V. TANGRI, J.S. SARFF, A.F. ALMAGRI, Y. REN, G. FIKSEL, S.C. PRAGER, University of Wisconsin-Madison — Cascading magnetic turbulence is observed in MST. However, the spectrum is better fit by exponential decay than a power law, suggesting dissipation is important. To probe the processes at play we extend the dissipation range energy transfer arguments of Corrsin[1] to MHD turbulence, and consider multiple dissipation mechanisms, including energy absorption by impurity ions from cyclotron resonance damping. The latter is believed to be important from anomalous ion heating observations. When cyclotron damping dominates at lower wavenumber than viscous or resistive dissipation, and the densities of multiple charge state impurities produce a cyclotron damping rate that is roughly constant in wavenumber, exponential decay in the dissipation range gives way to an inertial range power law at higher wavenumber. We fit the theoretical spectrum to MST data, obtaining values for the cyclotron damping rate and the turbulent dissipation rate. These are compared to independent theoretical calculations. Implications for solar wind and interstellar turbulence are discussed.

[1]S. Corrsin, Phys. Fluids 7, 1156 (1964).

JP8.00143 Preliminary Results from ULQ Experiments in RFX-mod

, R. PIOVAN, S. CAPPELLO, L. ZANOTTO, D. TERRANOVA, M. ZUIN, F. AURIEMMA, P. SCARIN, Consorzio RFX — Plasma configurations with Ultra-Low safety factor, ULq , have been set up in RFX-mod, a RFP study oriented machine (R=2m, a=0.46m). The first tests have been carried out with the following parameters: $I_p = 250 \div 500$kA, $q = 0.2 \div 0.6$, pulse length up to 100 ms, $I/N = 1 \div 5 \cdot 10^{-14}$A m. Plasma current evolution exhibits a staircase-like behaviour, likewise in other previous experiments, with a natural tendency to sustain the configurations with discrete *q* values at the edge, which are near to the major rational numbers. The plasma current flat phases are preceded by the raise of very large single modes, having n,m numbers depending on the q-value at the edge: a large kink deformation of the plasma column, with strong interaction with the wall, is present during that time. The flat current phase is characterized by both low and high frequency MHD activity (modes $m = 1$, $n = 1 \div 20$) with very low amplitude, more than one order of magnitude lower than the corresponding RFP pulses in RFX-mod. Very low I/N pulses have been established, with density near or slightly over the Greenwald limit and a peaked profile, differently from the RFP configurations of RFX in which the high density produced always hollow profiles. We report the details of the ULq experimental results and comparison with RFP plasmas, together with the plan for future experiments with improved *q*-value and plasma control.

JP8.00144 3D nonlinear MHD simulations for Ultra-Low q plasmas

, SUSANNA CAPPELLO, D. BONFIGLIO, R. PIOVAN, Consorzio RFX — Nonlinear 3D MHD simulations for Ultra-Low safety factor, ULq , plasmas have been performed with the SpeCyl code [1] in the simple frame of visco-resistive zero pressure model. This configuration is the intermediate state between the Tokamak and the Reversed Field Pinch. The experimental observation of the staircase-like behaviour in the evolution of the edge q-value, show that ULq plasmas have the natural tendency to select discrete q_{edge} which are about the major rational numbers, suggesting plasma self-organization. Similar behaviour is obtained in numerical modelling when driving the system from the RFP regime to the Tokamak one: the transition of the q-value somewhat inside the plasma edge from a plateau level (near the mode rational number) to the next one occurs in concomitance with the development of a kink deformation of the plasma column, whose stabilization yields a nearly axisymmetric state. This numerical study, and the preliminary experimental results obtained exploiting the flexibility of the experiment RFX-mod [2], indicate the possibility to explore the impact on transport of such different MHD behaviour within the same experiment [1]. S. Cappello & D. Biskamp Nuclear Fusion **36**, 571 (1996) [2] see on the web: R. Piovan, et al. *First results of Ultra-Low q experiments in RFX-mod* 12th IEA-RFP Workshop, Kyoto, Japan, 26-28 March 2007.

JP8.00145 Recent results of the RFX-mod Reversed Field Pinch

, P. MARTIN, S. ORTOLANI, RFX TEAM[1] — The experiments recently performed in the Reversed Field Pinch device RFX-mod are presented. The plasma operation regimes have been extended both in the current (0.3 MA$\leq$ Ip $\leq$ 1.5MA) and density space (0.1$\leq$n$_e$/n$_{Greenwald}$ $\leq$0.8). Temperatures above 1 keV have been obtained, with discharge durations as long as $\approx$ 0.5 s. RFX-mod is a state of the art facility for active control of MHD modes, with a set of 48 (toroidal) x 4 (poloidal) saddle coils, independently driven, which cover the whole plasma surface. The aliasing of the sidebands generated by the discrete saddle coils has been corrected in real time, and new results on RWM stabilization and tearing modes control will be presented. Various enhanced confinement regimes, such as Oscillating Poloidal Current Drive, Quasi Single Helicity states are discussed.

[1]Consorzio RFX - EURATOM-ENEA Association, Padova, Italy

JP8.00146 Stability Threshold of Ion Temperature Gradient Driven Mode in RFP plasmas[1]

, SHICHONG GUO, Consorzio RFX, Italy — The Ion Temperature Gradient driven (ITG) mode and the related transport are of current interest in the RFP community. To understand the behavior of this mode in RFP plasmas; as the first step, the linear threshold of ITG mode in the RFP configuration is investigated in the small Larmor radius limit. Compared to tokamak, RFP configuration has a shorter connection length and stronger magnetic curvature drift. These effects result in a stronger instability driving mechanism in the fluid limit. However, the kinetic damping effects (Landau and magnetic drift resonance) also become stronger than those in tokamak; which ultimately determine the stability threshold. The numerical analysis shows that the ITG (adiabatic electrons) instability in RFPs requires a rather steep temperature profile, which usually may not exist in the plasma core of the current RFP experiments. The required temperature slope may be found in the very edge of the plasma where the temperature cools down rapidly near vacuum vessel or near the board of the dominant magnetic island during the quasi-single helicity state of the discharge. The case of positive density gradient of the plasma and/or trapped electron effects will also be discussed.

[1]The author gratefully acknowledge Prof. Liu Chen for valuable discussions.

JP8.00147 Transport reduction and heating in the helical core of the reversed-field pinch, F. BONOMO, A. ALFIER, Consorzio RFX, Padova - Italy, S.V. ANNIBALDI, Space and Plasma Physics, Association Euratom-VR, EE, Royal Institute of Technology, SE-10044 Stockholm, Sweden, P. BURATTI, Associazione Euratom-ENEA, CR ENEA Frascati - Italy, R. PASQUALOTTO, P. PIOVESAN, G. SPIZZO, D. TERRANOVA, Consorzio RFX, Padova - Italy — We describe the use of the M1TeV transport code to interpret the strong heating which is observed inside magnetic islands in the core of a reversed-field pinch during the quasi-single helicity (QSH) state. M1TeV describes the evolution of an internal kink mode in a Tokamak, using helical flux coordinates[1]. We adapted the code to the q profile typical of the reversed-field pinch, and we stopped the reconnection process at an intermediate stage to study 2D electron heat diffusion. Results show that inside the magnetic island the heat transport coefficient is two orders of magnitude lower than in the chaotic background, and its values fall in the Tokamak range. The M1TeV code is also capable of reproducing quite well the observed temperature profiles measured by the Thomson Scattering diagnostic at the RFX-mod experiment in Padova, Italy.

[1]F.Porcelli *et al.*, Phys. Rev. Lett. **82**, 1458 (1999).

JP8.00148 Density limit, radiation and magnetic topology in the reversed-field pinch, M.E. PUIATTI, S. CAPPELLO, F. CARRARA, P. SCARIN, G. SPIZZO, D. TERRANOVA, M. VALISA, B. ZANIOL, Consorzio RFX, Euratom-ENEA Association, Corso Stati Uniti 4, 35127 Padova - Italy — In this paper we analyze the density limit in the reversed-field pinch machine RFX-mod, whose upgrades (in particular, the new feedback control system[1]) have greatly ameliorated plasma-wall interaction issues. In fact, when $n/n_G < 0.35$ (with n_G the Greenwald density), there is no signature of enhanced radiation outside the regions of the residual localized plasma-wall interaction. On the contrary, when $n/n_G > 0.35$ a localized enhancement of the radiation is observed, not necessarily associated to the region of maximum plasma-wall interaction. This localized radiation has the shape of a poloidal ring, and appears in correspondence to edge magnetic islands, originated from the MHD $m = 0$ modes (m is the poloidal mode number). Besides the local decrease of particle diffusivity D associated to the magnetic islands, the presence of highly radiating rings can be related to a reduction of the turbulent edge transport[2], which takes place approximately at the same values of n/n_G. In this respect, the microscopic cause of the density limit could be similar to the MARFE phenomenon in Tokamaks.

[1]S.Martini and the RFX team, Nucl. Fusion **47**, 783 (2007).
[2]see P.Scarin, this conference.

JP8.00149 Hydrodynamic mode associated with the pinch flow in RFP simulations, GIAN LUCA DELZANNO, LUIS CHACON, JOHN FINN, LANL — We present a systematic study of single helicity (SH) states and quasi-single helicity (QSH) states in RFPs. We begin with cylindrical paramagnetic pinch equilibria with uniform resistivity, characterized by a single dimensionless parameter proportional to the toroidal electric field, or the RFP toroidal current parameter Θ. For sufficiently high Θ, there are several unstable $m = 1$ ideal MHD instabilities, typically one of which is nonresonant, with $1/n$ just above $q(r = 0)$. We evolve these modes nonlinearly to saturation for low Hartmann number H. We show the existence of a new class of unstable modes [1], besides the electromagnetic kink modes typically responsible for the reversal of the axial magnetic field at the edge in RFPs. This new instability is hydrodynamic in nature and is due to the inward equilibrium pinch flow and suitable boundary conditions. In these circumstances, the total angular momentum of the system must grow in response to the flux of particles coming from the boundary. The hydrodynamic mode dominates the nonlinear phase of the velocity field but has little effect on the dynamics of the magnetic field.
[1] G.L. Delzanno, L. Chacón, J.M. Finn, Hydrodynamic mode associated with the pinch flow in Reversed Field Pinch simulations, submitted (2007).

JP8.00150 Kinetic effects in RFP plasma, VLADIMIR SVIDZINSKI, HUI LI, BRIAN ALBRIGHT, LANL — Strong tearing mode activity is present at sawtooth crashes in the Madison Symmetric Torus reversed field pinch (RFP). It is believed that tearing modes are responsible for strong ion heating and change in plasma flow profile at the crash. Our results based on both linear and nonlinear resistive MHD models showed that the spatial scale of velocity, electric field and current profiles in the tearing mode near resonance surface is comparable to ion gyroradius. The ion gyroradius is relatively large in RFPs because of smaller equilibrium magnetic field. In these conditions both two fluid and kinetic effects can be significant. We study ion kinetic effects on tearing modes in RFP plasmas. We consider RFP-like equilibrium in plane geometry and solve for linear eigenmodes in resistive MHD, two fluid and fully kinetic models. In the first two models we solve an eigenvalue problem, in the last we use particle in cell code VPIC and follow linear time evolution of the fastest growing mode. Also we examine nonlinear effects in tearing modes by running 2-D nonlinear time evolution in plane geometry in resistive MHD and PIC models. We analyze how the scale of plasma flow and flow amplitude in the mode are effected by the finite ion gyroradius effect, to what plasma component (ions or electrons) the magnetic energy of initially unstable equilibrium is transfered. Results of this analysis will be presented.

JP8.00151 Initial results from a low-aspect ratio RFP machine "RELAX"[1], S. MASAMUNE, A. SANPEI, H. HIMURA, R. IKEZOE, T. ONCHI, K. MURATA, K. OHKI, H. SHIMAZU, T. YAMASHITA, Kyoto Institute of Technology — The low-aspectratio (A) RFP may have the potential to open a new regime of RFP configurations in that its equilibrium has such an advantage for confinement improvement as less densely spaced mode rational surfaces in the core region. It might also be desirable for staedy state operation relying on the neoclassical bootstrap current. We have constructed a low-A RFP machine "RELAX" (**RE**versed field pinch of **L**ow-**A**spect ratio e**X**periment) with aspect ratio of 2 (R=0.51m/a=0.25m) to explore the new RFP regime. The RFP discharge parameters in initial RELAX experiments are as follows. The plasma current I_p is in the range from 40-80kA with discharge duration of ¿ 2ms. The discharge resistance R_p decreases with increasing I_p, from 4mΩ (at I_p=40kA) to 1mΩ (at I_p=80kA). The pinch parameter Θ tends to be somewhat higher (Θ = 1.8-3.0) and the field reversal parameter F, deeper (F = -0.5 - -1.0), when compared with those in medium- aspect ratio RFP. We will discuss on the MHD stability properties in RELAX by comparing the poloidal and toroidal mode spectra with experimental MHD equilibrium configurations.

[1]Work supported by a grant in aide from MEXT, Japan

JP8.00152 Characteristics of magnetized plasma flow for helicity injection into reversed-field pinch, SHOTARO SUZUKI, TOMOHIKO ASAI, Nihon Univ, MASAYOSHI NAGATA, Univ of Hyogo, HARUHISA KOGUCHI, YOICHI HIRANO, HAJIME SAKAKITA, SATORU KIYAMA, AIST, NIHON UNIV TEAM, UNIV OF HYOGO COLLABORATION, AIST TEAM — The magnetized plasma flow injection experiment has been performed on the large sized reversed-field pinch (RFP) device of TPE-RX. The magnetized plasma flow injection has been demonstrated to support RFP formation fueling and helicity injection. In the start-up experiment with the plasma flow injection, reduced density pump-out, loop voltage and Da emission have been observed clearly. Also the effect of plasma flow on the RFP with improved confinement by PPCD technique has been evaluated. To determine the efficiency of fueling and helicity injection, density, temperature and magnetic structure have been measured by using Langmuir and magnetic probe arrays.The series of experiments will show the magnetic structure and actual helicity and energy contents of injected magnetized plasma flow.

JP8.00153 ENERGETIC IONS AND ELECTRONS IN HELICONS —

JP8.00154 Measurements of Ion Flow and Neutral Depletion in an Argon Helicon Plasma with Magnetic Nozzle , CHRISTOPHER DENNING, MATT WIEBOLD, JOHN SCHARER, University of Wisconsin-Madison — Argon helicon plasmas are generated using 13.56 MHz RF power of up to 3 kW in a 10-cm-diameter Pyrex vacuum chamber attached to a 45-cm-diameter stainless steel chamber. Magnetic field strengths range up to 1 kG in the helicon source region and 1.5 kG at the peak of a downstream magnetic nozzle. 105 GHz microwave interferometry and a Langmuir probe are used to measure plasma densities in the range of 10^{12} - 4×10^{13} cm^{-3} with electron temperatures in the range of 4 - 8 eV. A maximum density is observed for any given neutral gas pressure in the range of 0.1 - 5 mTorr (at RF powers typically between 1 and 1.5 kW), decreasing for greater powers, suggesting neutral depletion. Tunable diode laser-induced fluorescence is used to examine ion dynamics in the presence and absence of a magnetic nozzle. Near-sonic (M = 0.7) ion flows of up to 2.7 km/s have been observed in initial experiments. The axial plasma potential variation is measured using probe diagnostics.

JP8.00155 Spectroscopic Measurements of Electron Temperature on the University of Texas at Austin Argon Helicon Experiment[1] , ELLA M. SCIAMMA, ROGER D. BENGTSON, W.L. ROWAN, The University of Texas at Austin, AMY M. KEESEE, West Virginia University, CHARLES A. LEE, DAN BERISFORD, The University of Texas at Austin — Absolutely calibrated spectroscopic measurements of the argon plasma in the helicon experiment at UT were used to estimate the electron temperature in the plasma core under the antenna. The helicon antenna was operated at 13.56 MHz with 1 kW absorbed power. Langmuir probe measurements of the electron density were used in a collisional-radiative model simulation[1] to estimate the electron temperature from argon ion (Ar II) line intensities. An electron temperature of 3.3 eV was obtained, agreeing with the Langmuir probe measurements. Argon neutral (Ar I) lines were then used with a second collisional-radiative model[2] to estimate the neutral density.

[1] http://adas.phys.strath.ac.uk
[2] Amy. M. Keesee and Earl E. Scime. Rev. Sci. Instrum. 77, 10F304 (2006)

[1]Work supported by Ad Astra Rocket Company and the Department Of Energy Office of Fusion Energy Science DE-FG03-00ER54609.

JP8.00156 Comparison between modeled and experimental emission rates in ASTRAL argon plasmas. , J. MUNOZ, R. BOIVIN, A. GARDNER, O. KAMAR, S. LOCH, Physics Department, Auburn University, 206 Allison Laboratory, Auburn, AL 36849, C. BALLANCE, Physics Department, Rollins College, White Park, FL 32789 — Argon emission rate coefficients are measured in the ASTRAL helicon plasma source using a 0.33 m scanning monochromator and a CCD camera. ASTRAL produces bright intense Ar plasmas with the following parameters: n_e = 10^{12} - 10^{13} cm^{-3} and T_e = 2 - 10 eV, B-field $\leq$ 1.3 kGauss, rf power $\leq$ 2 kWatt. A rf compensated Langmuir probe is used to measure T_e and n_e. In this experiment Ar I, Ar II and Ar III transitions are monitored as a function of T_e while n_e is kept constant. Thus, experimental emission rates are obtained as a function of T_e and compared to theoretical predictions. Using the ADAS suite of codes, we present spectral modeling of Ar plasmas produced in the ASTRAL helicon plasma source. Recent R-matrix electron-impact excitation data are combined with a new R-matrix calculation that includes pseudo-states contributions. Our collisional-radiative formalism assumes that the excited levels are in quasi-static equilibrium with the ground and metastable populations. Good to excellent agreement has been obtained by including T_e and n_e profiles in the modeling. The experiment-theory comparison confirms that T_e is the dominant parameters in determining the emission rate coefficients in these plasmas.

Tuesday, November 13, 2007 2:00PM - 5:15PM –

Session JM4 Mini-conference on Angular Momentum Transport in Laboratory and Nature II

Rosen Centre Hotel Salon 1/2

2:00PM JM4.00001 Angular momentum transport at early times[1] , ELLEN ZWEIBEL[2], University of Wisconsin, Madison — It is well known that angular momentum must be efficiently removed from interstellar clouds as they contract and eventually collapse to form stars. At the present epoch, angular momentum is transported primarily by magnetic fields. At the time the first stars formed, galactic magnetic fields were probably either absent or were much weaker than they are now. I will discuss the growth of magnetic fields in star forming regions and their role in angular momentum transport under primordial conditions.

[1]Supported by NSF through AST0507367 and the Physics Frontiers Program
[2]and Center for Magnetic Self-Organization

2:30PM JM4.00002 Heating and Angular Momentum Transport in Hot Accretion Flows[1] , PRATEEK SHARMA, ELIOT QUATAERT, University of California, Berkeley, GREGORY W. HAMMETT, JAMES M. STONE, Princeton University — The magnetorotational instability (MRI), an instability of magnetized differentially rotating plasmas, has been studied extensively with MHD. However, MHD is not a good description when the plasma mean free path is larger than the scales of interest. Sgr A*, the accretion flow around the supermassive black hole in the center of our Galaxy, is the prime example of a collisionless accretion flow. We use the kinetic MHD formalism (valid if Larmor radius $\ll$ length scales), closed with parallel heat fluxes, for local simulations of the collisionless MRI. Kinetic MHD differs from MHD in that the pressure is anisotropic with respect to the magnetic field lines. Pressure anisotropy ($p_\perp > p_\|$) results because of adiabatic invariance ($\mu \propto p_\perp/B =$ constant) as magnetic field is amplified by the MRI. Pressure anisotropy cannot become arbitrarily large; we use models of pressure isotropization by different microinstabilities so that $\Delta p/p \leq S/\beta^\alpha$. Anisotropic viscous stress, due to momentum transport by parallel free streaming particles, is comparable to the Maxwell stress. Moreover, electrons can be significantly heated due to anisotropic viscous stress. Large electron heating results in a significant radiative efficiency, ruling out the models which ascribe the low luminosity of Sgr A* to only a low efficiency; a supression of net mass accretion rate is required for the low luminosity.

[1]supported in part by a Sloan Fellowship, David and Lucile Packard Foundation, NASA grants NNG05GO22H and NNH06AD01I, and DOE grants DE-FC02-06ER41453, DE-AC02-76CH03073, and DE-FG52-06NA26217.

3:00PM JM4.00003 Evidence for the energetics, efficiency, and magnetic fields from BH angular momentum transport[1] , PHILIPP KRONBERG, LANL/University of Toronto — I will review what observations can tell us about the energetics and magnetic field structures in jets that are produced by black hole angular momentum transport. These show that this must be a very efficient process, which must put tight constraints on the "machine" that converts gravitational to magnetic energy. I also discuss limitations in the current observational diagnostics, which are mostly in the radio, and prospects for overcoming some of these in the near future.

[1]Supported by the US Department of Energy and NSERC(Canada)

3:30PM JM4.00004 Angular momentum transport and state transitions in magnetized black hole accretion disks[1]

EDISON LIANG, GUY HILBURN, Rice University, SIMING LIU, HUI LI, LANL, CHARLES GAMMIE, University of Illinois

— Black hole accretion disks exhibit multiple spectral states with distinct spectra and dynamical behaviors. While the origin of such spectral states remains a mystery, one likely cause is variation in the effective viscosity that transports angular momentum and drives the accretion flow. MHD turbulence driven by the magneto-rotational instability (MRI) is currently the favored candidate of viscosity. Saturation of the MRI instability regulates the accretion flow, but its effect on global spectral states remains an open question. Using MHD simulations and semi-analytic accretion disk models, we have studied the role of magnetic fields in accretion disk emissions and dynamics. In this paper we first review observational data of black hole spectral states and their implications for accretion disk structure, evolution and viscosity. We then report new results of the spectral-temporal manifestations of MRI-driven accretion flows, including the effects of radiative cooling (cyclo-synchrotron, bremsstrahlung, Compton), electron heating by MHD turbulence and strong ordered seed fields.

[1]work partially supported by NSF AST0406882.

3:45PM JM4.00005 Magnetic Field Configurations Associated With Angular Momentum Transport in Astrophysics and the Accretion Theory of Spontaneous Rotation in the Laboratory*

, B. COPPI, MIT

— Differentially rotating structures in the prevalent field of a central object have been shown to develop a "crystal" magnetic structure resulting from toroidal internal currents and leading to the formation of density ring sequences[1] rather than disks. Poloidal current densities with appropriate symmetries are found to be connected with angular momentum transport processes represented by an effective viscosity. Jets are suggested to consist of a series of stable "smoke- rings" ejected vertically in opposite directions from the central region of the considered ring sequence. A small inward flow velocity is shown to induce a spiral pattern in the magnetic field lines on a selected family of magnetic surfaces. The accretion theory[2] of the spontaneous rotation phenomenon in toroidal laboratory plasmas relies on the ejection of angular momentum toward the surrounding material wall, by collisional ballooning modes excited at the edge, whose phase velocity depends on collisionality. The resulting recoil gives rise to the rotation of the main body of the plasma column as other plasma modes (called VTG) provide the needed inward transport of angular momentum. *Sponsored in part by the US D.O.E.

[1]B. Coppi and F. Rousseau, *Ap. J.* **641**, 458 (2006)
[2]B. Coppi, *Nuc. Fus.* **42**, 1 (2002)

4:00PM JM4.00006 Studying the Physics of AGN Jets Near Their Origin[1]

, DANIEL HOMAN, Denison University

— I will discuss the use of Very Long Baseline Array (VLBA) observations to probe the Physics of jets from Active Galactic Nuclei (AGN) on parsec scales, near their origin from the accretion disk/super massive black hole system. These high resolution observations can study not only the kinematics, acceleration, and collimation of these relativistic jets, but also their spectral and polarization properties. Polarization, whether intrinsic to the emitted synchrotron radiation or the result of birefringence effects within the jet, serves as a probe of the particle population and the 3-D magnetic field structure of jets, and I will discuss results from recent and ongoing work to constrain these properties.

[1]This work has been supported by Research Corporation and NSF Grant AST-0707693

4:30PM JM4.00007 Momentum Transport by Current-Driven Reconnection[1]

, S.C. PRAGER, A. ALMAGRI, D.J. DEN HARTOG, F. EBRAHIMI, G. FIKSEL, A. KURITSYN, M. MILLER, V. MIRNOV, J. SARFF, University of Wisconsin, and Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, D. BROWER, W. DING, University of California, Los Angeles, D. CRAIG, Wheaton College

— Radial transport of poloidal and toroidal angular momentum is rapid during a global reconnection event in the MST reversed field pinch experiment. Theoretical explanation has evolved for transport from Maxwell and Reynolds stresses from multiple nonlinearly coupled tearing modes. Comparing stresses from multimode computation with those for a single mode shows that nonlinear coupling (multiple reconnections) greatly enhances transport. Measurement of stresses in MST (edge and core) supports, but does not yet completely confirm, this explanation. In the edge, Reynolds and Maxwell stresses are very large and oppositely directed, with the difference of order of the measured inertial (acceleration) term. These results raise the possibility that current-driven instability (reconnection) could be active in astrophysical accretion disks, for which flow-driven instability is the leading explanation. Thus, we have begun computation of transport from current-driven instability in disks.

[1]Supported by DOE and NSF

5:00PM JM4.00008 An Unmagnetized, Plasma Couette flow for investigating the Magnetorotational Instability

, CARY FOREST, University of Wisconsin, Madison

— A new plasma experiment to investigate the magnetorotational instability, dynamos, and other fundamental plasma processes for astrophysics is proposed. The experiment consists of a vacuum chamber with a series of permanent magnetics, with electrically insulated pole faces, in a ring cusp geometry (poles facing inward with alternating polarity along the vessel wall). The resulting field is axisymmetric and decays quickly away from the walls providing a large, magnetic field free region in the center of the device. To stir the plasma, cathodes positioned between the magnet rings are biased such that the resulting electric field induces plasma rotation through the ExB drift. The flow drive principle is quite general and simulations indicate that the high magnetic Reynolds number plasmas flows can in principle be generated that are unstable to the magnetorotational instability. Use of a plasma for such an experiment may allow the magnetic Reynolds number (the dimensionless parameter governing self-excitation of magnetic fields) to be approximately a factor of 10 larger than in liquid metal experiments and will be the first experiment to investigate the MRI in a plasma, the state of matter that makes up naturally occurring accretion disks.

Tuesday, November 13, 2007 2:00PM - 4:00PM –

Session JM5 Mini-conference on Energetic Ions and Electrons in Helicon Sources Rosen Centre Hotel Salon 11/12

2:00PM JM5.00001 PIC Modeling of Argon Plasma Flow in MNX[1]

, SAMUEL COHEN, ADAM SEFKOW, Princeton Plasma Physics Laboratory

— A linear helicon-heated plasma device - the Magnetic Nozzle Experiment (MNX) at the Princeton Plasma Physics Laboratory - is used for studies of the formation of strong electrostatic double layers near mechanical and magnetic apertures and the acceleration of plasma ions into supersonic directed beams. In order to characterize the role of the aperture and its involvement with ion acceleration, detailed particle-in-cell simulations are employed to study the effects of the surrounding boundary geometry on the plasma dynamics near the aperture region, within which the transition from a collisional to collisionless regime occurs. The presence of a small superthermal electron population is examined, and the model includes a background neutral population which can be ionized by energetic electrons. By self-consistently evaluating the temporal evolution of the plasma in the vicinity of the aperture, the formation mechanism of the double layer is investigated.

[1]This work was supported, in part, by U.S. Department of Energy Contract No. DE-AC02-76-CHO-3073.

2:20PM JM5.00002 Double layers in the Chi-Kung helicon source, CHRISTINE CHARLES, Australian National University — A current-free double layer (DL) spontaneously forms near the exit of the Chi-Kung helicon source at low pressure with an applied diverging magnetic field for electropositive and electronegative gases. Ion energy distribution functions measured with an energy analyser show a low divergence, accelerated ion beam downstream of the DL. The glass plate terminating the source presents some positive charging and its sheath potential, measured with a planar wall probe, is found to the greater than the DL potential drop. The energy distributions of the trapped and free electrons are measured using a rf compensated probe. Upstream of the DL the EEDF shows a very clear change in slope at energies corresponding to the double layer potential drop. Electrons with lower energy are Maxwellian with a temperature of 8 eV whereas those with higher energy have a temperature of 5 eV. The EEDF in the downstream plasma also has a temperature of 5 eV, suggesting that the downstream electrons come from upstream electrons that have sufficient energy to overcome the potential of the double layer, and that only a single upstream plasma source is required to maintain this phenomenon. Results on the transition from a non-DL plasma to a DL plasma are also presented.

2:40PM JM5.00003 Argon neutral LIF measurements are consistent with no energetic electron population, AMY KEESEE, EARL SCIME, West Virginia University — Most studies in plasma physics are devoted to studying the ions and electrons that make up plasma. However, any plasma that is not 100% ionized will interact with the neutral gas present in the experiment. Understanding these neutrals can help us better understand plasma characteristics and how neutrals affect the plasma. Measurement of the neutral atoms is available with spectroscopic diagnostics such as laser-induced fluorescence (LIF) and passive emission spectroscopy of neutral lines. However, these measurements apply to an excited neutral atom state, rather than the entire neutral population. A collisional-radiative model describes the relationship between densities of the excited states, given electron densities and energy distributions. Using electron data obtained via Langmuir probe measurements, a collisional-radiative model code is used to compare radial profiles of theoretical excited state densities to those measured experimentally with LIF and passive emission spectroscopy in a helicon source with argon gas. The CR model radial neutral density and electron distribution function profiles can be varied to obtain the best comparison with experimental data. For plasma in helicon mode, the model results best match the experimental data when the radial neutral profile is hollow and electron population consists of a single Maxwellian electron distribution with no energetic electron population.

3:00PM JM5.00004 Excited Ar II Emission Characteristics in Helicon Plasmas, JOHN SCHARER, CHRISTOPHER DENNING, MATT WIEBOLD, University of Wisconsin-Madison, ALEX DEGELING, University of Alberta, ROD BOSWELL, Australian National University — Wave field, peak Ar II 443 nm emission, and antenna code modeling have shown phase velocities in helicon sources that are in close agreement for moderate density and magnetic field (n_e =1.2-4 x 10^{12} /cc and 100-200 G) experiments at the Australian National University and University of Wisconsin. The phase velocities correspond to parallel electron energies in the range of 16-46 eV and the peak electron density occurs 10-15 cm from the end of the antennas indicating that fast accelerated electrons may play a role in helicon source operation. Higher plasma density experiments (>2-8x10^{12} cm^{-3} and higher magnetic fields) on the Australian National University and University of Wisconsin helicon facilities have both shown a peak excited Ar II 443 nm rf modulated emission signal that is in phase along the direction parallel to the magnetic field when the plasma is in the dense helicon (or "blue") mode. Interpretations of these observations and recent measurements will be presented.

3:20PM JM5.00005 Double layers in electronegative plasmas, ALBERT MEIGE, N. PLIHON, P. CHABERT, G.J.M. HAGELAAR, J.-P. BOEUF, Ecole Polytechnique, R.W. BOSWELL, Australia National University, M.A. LIEBERMAN, A. LICHTENBERG, University of California-Berkeley — Current-free double layers observed in Helicon sources have attracted much interest, both due to their potential applications in space propulsion for example and because of their fundamental properties. In the case of electropositive plasmas, double layers that have been reported are always static and their amplitude is a decreasing function of pressure (within their range of existence), while in the case of electronegative plasmas, they have also been observed to propagate and their amplitude is essentially independent of pressure. In the present paper, focus is put on the static and propagating double layers that have been observed in a Helicon-type reactor filled up with a low-pressure mixture of Ar/SF6: the most significant experimental results are reviewed, an analytical model describing the static double layer is presented and a fully self- consistent hybrid simulation is developed to shed light on the propagating double layer. From this, a formation mechanism is proposed.

3:40PM JM5.00006 Ion Acceleration in a Compact Helicon Source with Various Permanent Magnet Configurations, KONSTANTIN SHAMRAI, VALERY VIRKO, YURY VIRKO, Institute for Nuclear Research, NAS of Ukraine, Kiev 03680, Ukraine — The parameters of plasma and emergent ion beam were examined in a 4.5-cm-diam compact helicon source excited by a double-turn $m = 0$ antenna and equipped with a multi-component permanent magnet system. The basic magnetic configuration was formed by a radially magnetized cylindrical assembly of the ferrite bars. It could be enhanced by an axially magnetized annular ferrite that was installed near the source outlet to create the magnetic nozzle. The magnetic configuration was found to be a crucial point for production of accelerated ions. At Ar pressure below 1 mTorr and rf power of 600 W, plasma potential in the discharge chamber was 100-120 V, which is by 50-60 V higher than in the drift chamber, but the emergent beam of accelerated ions arose only in the presence of the magnetic nozzle. This implies that electrostatics might not be the only driver for ion acceleration. The beam of accelerated ions had energies up to 120 eV, relative to ground, and the current up to 40 mA, whereas the electron temperature in the discharge chamber was 10-12 eV. The source parameters were optimized by installing various ferrite assemblies and the outlet ferrite shield, and also by testing various driving antennas and frequencies.

Tuesday, November 13, 2007 3:00PM - 5:00PM –

Session KI2 Plasma Based Accelerators and Sources Rosen Centre Hotel Salon 3/4

3:00PM KI2.00001 Laser Wakefield Structures and Electron Acceleration in Gas Jet and Capillary Discharge Plasmas[1], ANATOLY MAKSIMCHUK, University of Michigan — Laser-driven plasma wakefield accelerators have the potential to become the next generation of particle accelerators because of the very high acceleration gradients. The beam quality from such accelerators depends critically on the details plasma wave spatial structures. In experiments at the University of Michigan it was possible in a single shot by frequency domain holography (FDH) to visualize individual plasma waves produced by the 40 TW, 30 fs Hercules laser focused to the intensity of 10^{19} W/cm^2 onto a supersonic He gas jet [1]. These holographic "snapshots" capture the evolution of multiple wake periods, and resolve wavefront curvature seen previously only in simulations. High-energy quasi-monoenergetic electron beams for plasma density in the specific range $1.5\times10^{19} \leq n_e \leq 3.5\times10^{19}$ cm^{-3}were generated [2]. The experiments show that the energy, charge, divergence and pointing stability of the beam can be controlled by changing n_e, and that higher electron energies and more stable beams are produced for lower densities. An optimized quasi-monoenergetic beam of over 300 MeV and 10 mrad angular divergence is demonstrated at a plasma density of n_e=1.5×10^{19} cm^{-3}. The resulted relativistic electron beams have been used to perform gamma-neutron activation of ^{12}C and ^{63}Cu and photo-fission of ^{238}U with a record high reaction yields of $\sim$5x10^5/Joule [3]. Experiments performed with ablative capillary discharge plasma demonstrate stable guiding for laser power up to 10 TW with the transmission of 50% and guided intensity of $\sim10^{17}$ W/cm^2. Study of the staged electron acceleration have been performed which uses ablated plasma in front of the capillary to inject electrons into the wakefield structures.

[1] N. H. Matlis et. al., Nature Physics **2,** 749 (2006).
[2] A. Maksimchuk et. al., Journal de Physique IV **133**, 1123 (2006).
[3] S. A. Reed et. al., Appl. Phys. Lett. **89**, 231107 (2006).

[1]Supported by the NSF through the Physics Frontier Center FOCUS, grant PHY-0114336.

3:30PM KI2.00002 Ultra-high-order harmonic generation in cavitated plasmas[1] , CARL SCHROEDER, Lawrence Berkeley National Laboratory — High-harmonic generation (HHG) using short pulse lasers in gases is a compact method for producing ultrafast, coherent light, but has been limited to the soft x-ray and extreme-ultraviolet spectral regions. The energy of the HHG photons can be increased by increasing the laser intensity and/or the ionization potential of the atom (or ion). At high laser intensities, however, HHG is suppressed by ionization and plasma production, limiting the coherence length via plasma-induced phase slippage. Phase-matching to overcome the plasma-induced slippage has been a critical challenge to further development of HHG x-ray sources. In this talk a novel method for producing hard x-rays via HHG from highly-stripped ions using ultra-intense lasers is described. The method relies on electron cavitation and ion channel formation by the ponderomotive force of an ultra-intense laser pulse or the space-charge force of a relativistic (laser-plasma-accelerated) electron beam. An intense, short-pulse laser propagating in the electron-free ion cavity can produce laser harmonics. A counter-propagating laser pulse train is proposed for quasi-phase matching via periodic suppression of the longitudinal electron motion owing to the magnetic component of the nonlinear Lorentz force for relativistic laser intensities. This method enables the reach of HHG to be extended to the sub-Å regime.

[1]Supported by the U.S. Department of Energy under Contract DE-AC02-05CH11231 and the National Science Foundation.

4:00PM KI2.00003 Interaction of intense ultrashort pulse lasers with clusters.[1] , GEORGE PETROV, Naval Research Laboratory, Washington, DC — The last ten years have witnessed an explosion of activity involving the interaction of clusters with intense ultrashort pulse lasers. Atomic or molecular clusters are targets with unique properties, as they are halfway between solid and gases. The intense laser radiation creates hot dense plasma, which can provide a compact source of x-rays and energetic particles. The focus of this investigation is to understand the salient features of energy absorption and Coulomb explosion by clusters. The evolution of clusters is modeled with a relativistic time-dependent 3D Molecular Dynamics (MD) model [1]. The Coulomb interaction between particles is handled by a fast tree algorithm, which allows large number of particles to be used in simulations [2]. The time histories of all particles in a cluster are followed in time and space. The model accounts for ionization-ignition effects (enhancement of the laser field in the vicinity of ions) and a variety of elementary processes for free electrons and charged ions, such as optical field and collisional ionization, outer ionization and electron recapture. The MD model was applied to study small clusters (1-20 nm) irradiated by a high-intensity (10^{16}-10^{20} W/cm^2) sub-picosecond laser pulse. We studied fundamental cluster features such as energy absorption, x-ray emission, particle distribution, average charge per atom, and cluster explosion as a function of initial cluster radius, laser peak intensity and wavelength. Simulations of novel applications, such as table-top nuclear fusion from exploding deuterium clusters [3] and high power synchrotron radiation for biological applications and imaging [4] have been performed. The application for nuclear fusion was motivated by the efficient absorption of laser energy (~100%) and its high conversion efficiency into ion kinetic energy (~50%), resulting in neutron yield of 10^6 neutrons/Joule laser energy. Contributors: J. Davis and A. L. Velikovich. [1] G. M. Petrov, *et al Phys. Plasmas* **12** 063103 (2005); **13** 033106 (2006) [2] G. M. Petrov, J. Davis, *European Phys. J. D* **41** 629 (2007) [3] G. M. Petrov, J. Davis, A. L. Velikovich, *Plasma Phys. Contr. Fusion* **48** 1721 (2006) [4] G. M. Petrov, J. Davis, A. L. Velikovich, *J. Phys.* B 39 4617 (2006)

[1]This work was supported by ONR under the NRL 6.1 program.

4:30PM KI2.00004 Increased Efficiency of Short-Pulse Laser Generated Proton Beams from Novel Flat-Top Cone Targets[1] , KIRK FLIPPO, Los Alamos National Laboratory — Ion-driven Fast Ignition (IFI) may have significant advantages over electron-driven FI (EFI) due to a large reduction in the ignitor beam and laser driver energy requirements. Recent experiments at the LANL Trident facility, using novel flat-top cones made by Nanolabz in Reno Nevada, have yielded a 4 fold increase in laser-ion conversion efficiency, a 13 fold increase in the number of ions above 10 MeV, and a two fold increase in the maximum proton energy as compared to Au flat-foil targets. If efficiencies scale with intensity, in accordance with flat-foils, then IFI would have an even bigger advantage over EFI. At a modest intensity of 10^{19} W/cm^2 with 20 Joules in 600 fs protons with at least 30 MeV were observed from the cone targets. Particle in Cell (PIC) simulations show that the maximum cutoff energy could have been as high as 40 MeV. The simulations indicate that the observed energy and efficiency increase can be attributed to the cone's ability guide and focus the laser, allowing more laser-light to be absorbed into the electrons. The cone's geometry then funnels the electrons to the flat-top. The small size also limits the number of electrons, allowing more to be heated to high temperatures, creating a hotter, denser sheath. The PIC simulations elucidate the critical parameters in obtaining superior proton acceleration such as the dependence on laser contrast/preplasma-fill and longitudinal and transverse laser pointing. In addition, these cones have the potential to revolutionize ICF target design and fabrication via mass production.

[1]Work was performed at LANL for the DOE under contract number DE-AC52-06NA25396, with support from the LANL LDRD program and the DOE OFES.

Wednesday, November 14, 2007 8:00AM - 9:00AM – Session MR1 Review: Plasma Physics Challenges of High Power Microwave Generation Rosen Centre Hotel Junior Ballroom

8:00AM MR1.00001 Plasma Physics Challenges of MM-to-THz and High Power Microwave Generation , JOHN BOOSKE[1], University of Wisconsin-Madison — Homeland security and military defense technology considerations have stimulated intense interest in mobile, high power sources of millimeter-wave to terahertz regime electromagnetic radiation, from 0.1 to 10 THz. While sources at the low frequency end, i.e., the gyrotron, have been deployed or are being tested for diverse applications such as WARLOC radar and active denial systems, the challenges for higher frequency sources have yet to be completely met for applications including noninvasive sensing of concealed weapons and dangerous agents, high-data-rate communications, and high resolution spectroscopy and atmospheric sensing. The compact size requirements for many of these high frequency sources requires miniscule, micro-fabricated slow wave circuits with high rf ohmic losses. This necessitates electron beams with not only very small transverse dimensions but also very high current density for adequate gain. Thus, the emerging family of mm-to-THz e-beam-driven vacuum electronics devices share many of the same plasma physics challenges that currently confront "classic" high power microwave (HPM) generators [1] including bright electron sources, intense beam transport, energetic electron interaction with surfaces and rf air breakdown at output windows. Multidimensional theoretical and computational models are especially important for understanding and addressing these challenges. The contemporary plasma physics issues, recent achievements, as well as the opportunities and outlook on THz and HPM will be addressed. [1] R.J. Barker, J.H. Booske, N.C. Luhmann, and G.S. Nusinovich, Modern Microwave and Millimeter-Wave Power Electronics (IEEE/Wiley, 2005).

[1]Electrical and Computer Engineering Department

Wednesday, November 14, 2007 9:30AM - 12:30PM – Session NI1 Electron Confinement and Zonal Flows Rosen Centre Hotel Junior Ballroom

9:30AM NI1.00001 Experimental Studies of Zonal Flow and Field in CHS Plasma , AKIHIDE FUJISAWA, National Institute for Fusion Science — Turbulence is a fundamental phenomenon ubiquitously observed in nature. In the fusion and plasma research, the drift-wave turbulence has been extensively studied to clarify the anomalous transport that degrades plasma confinement properties. Recently, a new paradigm for plasma turbulence has come up: the turbulence is regarded as a system of drift waves and the zonal flows. This paper provides full reports on the pioneer works in CHS, which have propelled the paradigm shift by dual heavy ion beam probes (HIBPs) and by modern data-processing techniques (wavelet, bicoherence, etc). In the experiments up to date, I) zonal flow was identified for the first time with the oscillatory branch of zonal flow, geodesic acoustic modes. II) The coupling between zonal flow and turbulence was confirmed. III) The difference in the energy partition between zonal flow and turbulence is found to be a cause of the confinement improvement for the states with and without a transport barrier. Very recently, the experiments have evolved into a new stage by exploring the potentiality of HIBP, that is, the ability to measure local magnetic field perturbation. The application resulted in discovery of zonal magnetic field and the coupling with turbulence. Similarly to the zonal flow, the zonal field is a symmetric structure around the magnetic axis with a finite radial wavelength in meso-scale. The discovery presents clear evidence that turbulence can generate the structured magnetic field, giving an insight into the field generation like geomagnetism. The works provide a modern framework for a fundamental understanding of the turbulence and its related structural formation. The observations of structured electric and magnetic fields generated by turbulence in laboratory are important for fluid mechanics and astronomy as well as the plasma physics.

10:00AM NI1.00002 Electron Temperature Fluctuations in the Core of High-Performance DIII-D Plasmas[1] , A.E. WHITE, UCLA — Electron temperature fluctuations have been measured for the first time in the core of high-performance, neutral-beam-heated DIII-D plasmas. Simultaneous local characterization of temperature and density fluctuations presents an opportunity to challenge theoretical/simulation predictions. Data from long-duration quiescent H-mode plasmas indicate that, at r/a=0.75, normalized fluctuation levels are reduced by a factor of 5 below L-mode levels, with a detectability limit of $\leq$0.25%. In these QH-mode plasmas, the absolute temperature fluctuation amplitude is observed to decrease by a factor of 2, correlating with increasing electron temperatures and improved electron thermal confinement. Temperature fluctuation levels and frequency spectra, $k_\theta \rho_s \leq$0.5, are determined via correlation electron cyclotron emission radiometry [1]. In L-mode, temperature fluctuations (20< f <250 kHz) increase with radius from $\sim$0.5% at r/a=0.5 to $\sim$2% at r/a=0.8, similar to local ñ measurements performed simultaneously with the beam emission spectroscopy diagnostic. The evolving frequency spectra reflect a Doppler-shift caused by E×B plasma rotation that dominates the intrinsic dispersion of the underlying instabilities. Linear gyrokinetic calculations at low-k for these L-mode plasmas indicate increasing growth rate with radius consistent with the observed profile of temperature fluctuations. These initial calculations will be extended to include nonlinear gyrokinetic simulations to provide a more critical comparison between experiment and theory. In particular, variations in the temperature and density fluctuation levels during neutral beam heated L-mode plasmas, with and without electron cyclotron heating, will be compared to code predictions.
[1] G. Cima, et al., Phys. Plasmas **2**, 720 (1995).

[1]Supported by US DOE under DE-FG03-01ER54615, JP333701, and a DOE-ORISE fellowship.

10:30AM NI1.00003 Gyrokinetic δf particle simulation of trapped electron mode driven turbulence[1] , JIANYING LANG, University of Colorado at Boulder — Turbulent transport driven by collisionless trapped electron modes (CTEM) is systematically studied using gyrokinetic delta-f particle-in-cell simulation. Scaling with local plasma parameters, including density gradient, electron temperature gradient, magnetic shear, temperature ratio and aspect ratio, is investigated. Simulation results are compared with previous simulations and theoretical predictions. Nonlinearly the transport level increases with increasing magnetic shear. We explain the nonlinear magnetic shear scaling by differences in the radial correlation lengths caused by toroidal coupling. The turbulence is more radially elongated at higher magnetic shear compared with low magnetic shear. We show that the suppression effect of zonal flow on CTEM transport depends on both the electron temperature gradient and the electron to ion temperature ratio. This helps explain the previous contradictory conclusions on the importance of zonal flows in different parameter regimes.[2] Zonal flow suppression is consistent with the rate of EXB shearing from the ambient turbulence as well as the radial broadening of the spectra. Strong geodesic acoustic modes (GAMs) are generated along with zonal flows and the frequency of the GAMs agrees well with kinetic theory.[3] We further explore the nonlinear saturation mechanism when the zonal flows are not important. We find that when only a single toroidal mode (and its conjugate) is kept, reasonable nonlinear saturation is obtained. Investigating a range of n, modes with larger mode number n saturate at a higher level relative to lower n modes, indicating a turbulent inverse cascade process.

[1]This work is supported by the SciDAC Gyrokinetic Particle Simulation Center and the Center for Plasma Edge Simulation.
[2]T. Dannert, F. Jenko, Phys. Plasmas 12, 072309 (2005); D. Ernst, et al., Phys. Plasmas 11, 2637 (2004).
[3]T. Watari, et al., Phys. Plasmas 13, 062504 (2006).

11:00AM NI1.00004 A quantitative account of electron energy transport in an NSTX plasma*
, KING-LAP WONG, Princeton Plasma Physics Lab — Anomalous electron transport in magnetized plasmas can be a major obstacle in the way toward practical nuclear fusion power, and it has been an outstanding problem for almost half a century. Here we report the first successful quantitative accounting of the electron thermal conductivity χ_e in a tokamak experiment due to imperfect magnetic surfaces[1] caused by the microtearing instabilities. The unstable spectrum is calculated with the GS2 code for a well-behaved H-mode plasma in NSTX (R/a=0.85m/0.67m) with 6 MW deuterium neutral beam heating at I_p=0.75 MA, B_t=0.5 T. The application of existing nonlinear theory[2] showed that the unstable modes can produce overlapping resistive layers and stochastic magnetic fields. The calculated χ_e based on the theory[1] is in good agreement with the values from transport analysis of the experimental data over the entire region (0.4 < r/a < 0.75), where the electron temperature gradient is strong enough to make microtearing the most unstable mode. There is no adjustable parameter in this comparison. In a discharge with reversed central magnetic shear and an L-mode edge, microtearing modes are found to be stable. The central electron temperature is 50% higher (2 keV vs 1.3 keV) than in the comparison shot with the microtearing instability and the same controlled tokamak parameters like plasma current, density, magnetic field, plasma shape, position and neutral beam heating power. This is a strong indication that this instability may be the dominant mechanism responsible for the electron transport in this type of plasma. Since the microtearing mode is difficult to stabilize with velocity shear, this instability is an important limit[3] on the electron temperature in spherical tokamak configurations where the usual long wavelength instabilities are not present.
*This work is carried out in collaboration with Drs. S. Kaye, D. R. Mikkelsen, J. Krommes, K. Hill, R. Bell, and B. LeBlanc. It is supported by US-DoE contract No. DE-AC02-76CH03073.
[1]A. B. Rechester, M. N. Rosenbluth, Phys. Rev. Lett. 40, 38 (1978).
[2]J. F. Drake et al., Phys. Rev. Lett. 44, 994 (1980).
[3]M. Kotschenreuther, W. Dorland et al., Nucl. Fusion 40, 677 (2000).

11:30AM NI1.00005 The Relationship between Type I ELM Severity and Perturbed Electron Transport in NSTX[1] , KEVIN TRITZ, Johns Hopkins University — NSTX provides a unique test bed for probing electron transport due both to its significant role in the steady-state power balance and features of the electron response to transient perturbations. In neutral-beam-heated plasmas in NSTX, most of the heating power is deposited on the electrons. Following large Type I ELMs in some H-mode NSTX discharges, global Te profile declines of 10-30% amplitude are observed. While the soft X-ray data indicates that the ELM itself is causing only a peripheral T_e perturbation, the inward propagation of the cold pulse initiated by the ELM is unusually fast (∼ms timescale) and can extend to the core of the plasma. The perturbed electron thermal diffusivity is ∼300 m^2/s for r/a > 0.4, and ∼30 m^2/s for r/a < 0.4. However, in high-triangularity regimes, which exhibit smaller Type I ELM perturbations and an energy loss of a few percent, the perturbation propagation time of several ms implies a perturbed electron thermal diffusivity of 10-20 m^2/s across the plasma radius. Comparison of the ELM energy loss with the electron thermal diffusivity inferred from both ELM and pellet induced 'cold pulses', shows a rough proportionality between the ELM magnitude and the perturbed electron thermal diffusivity. Furthermore, comparisons of the linear growth rates of instabilities calculated with the GS2 code show large differences between the large and small Type I ELM regimes. In particular, the ETG mode is the dominant instability following large ELMs, but absent during the small Type I ELM. Interestingly, high-k measurements during ELM events show an increase of short wavelength fluctuations in both the core and edge regions of the plasma, with the increase in amplitude most prominent at wavenumbers of 14-16 cm^{-1}. These results suggest that electron thermal transport plays an important role in determining the total energy loss from Type I ELMs.

[1]supported by US DOE contract DE-AC02-76CH03073 at PPPL.

12:00PM NI1.00006 Spectral Features of the Geodesic Acoustic Mode and its Interaction with Turbulence in a Tokamak Plasma , CHANG-XUAN YU, USTC, China — The measurements of the geodesic acoustic mode (GAM) by a set of probe arrays with large poloidal and toroidal separations in the edge region of the HL-2A tokamak have been performed. By the two-point cross-correlation technique, the three-dimensional wavenumber and frequency spectrum for the GAM is measured for the first time. The spectrum for the GAM exhibits a anisotropic feature: the poloidal and toroidal wavenumber spectra are peaked at $k_\theta = k_\phi = 0$ with a width given by the spectral variance, while the radial spectrum shows a peak in the range of $q_r\rho_i \simeq 0.05 \sim 0.09$ with the FWHM of$\Delta q_r\rho_i \simeq 0.04 \sim 0.07$. The spectrum also shows the GAM propagates in the radially outward direction. Using a newly developed method based on the poloidal momentum equation, the generation of the GAM by the triad interaction of turbulence via the Reynolds stress has been directly measured. The result manifests that the energy is transferred from small scale turbulence into the GAM by the gradient of the Reynolds stress and the GAM saturation amplitude is determined by balancing between the generation and damping rates of the GAM. In addition, it is found that the envelope of the radial electric field fluctuations $\tilde{E}_r$ is modulated by the GAM and the cross-phase between the envelope and GAM oscillation is aboutπ. The numerical investigation shows that the modulation of the $\tilde{E}_r$ envelope is dominantly induced by the amplitude modulation. This fact together with the anti-phase relation between the $\tilde{E}_r$ envelope and GAM oscillation imply that the modulation of the $\tilde{E}_r$envelope is accompanied with the GAM generation in the energy-conserving triad interaction. These results suggest that the GAM is generated dominantly by the parametric instability driven by the turbulent Reynolds stress. In collaboration with T. Lan, A.D. Liu (USTC, China); L.W. Yan, W.Y. Hong, K.J. Zhao, J. Q. Dong, Q.W. Yang (SWIP, China).

Wednesday, November 14, 2007 9:30AM - 12:30PM –
Session NI2 MHD, Strongly Coupled and Low Temperature Plasmas Rosen Centre Hotel Salon 3/4

9:30AM NI2.00001 Ion Heating During Reconnection in the Madison Symmetric Torus , DARREN CRAIG, Wheaton College and the Center for Magnetic Self Organization in Laboratory and Astrophysical Plasmas — New spatially and temporally resolved measurements of ion temperature in MST provide new insight into the long observed ion heating associated with reconnection, and strong constraints on possible theories for the heating. Ion heating in MST is a strong effect, with a transient heating power of up to 50 MW during large reconnection events, resulting in ion temperatures > 2 keV in high current plasmas. Recently, such ion heating has been used to good effect: to produce high ion temperatures that are then sustained during plasma periods with improved confinement. The heating power during a reconnection event derives from a drop in global stored magnetic energy. Two diagnostic neutral beams are used to make fast localized measurements of impurity ions (via fast charge exchange recombination spectroscopy) and majority ions (via Rutherford scattering). Spatial profiles of the heating show a link between where reconnection occurs and where heating occurs. During large reconnection events involving many coupled reconnection sites, a broadly distributed heating profile is observed. Conversely, heating is localized to the edge in smaller reconnection events involving only edge resonant modes. Impurities are heated more strongly than bulk deuterium ions in deuterium plasmas (by about a factor of 2). This suggests a dependence on mass or charge. Many potential ion heating theories have been advanced but all fail to capture all of the observed features. Recent calculations evaluate viscous and cyclotron damping. Viscous damping of tearing mode flows could be important if strong, localized flow gradients are present, encouraging a search for such flows. A cascade of fluctuation power to ion gyroradius scales appears too weak for direct bulk heating, but could be important for impurity heating. Magnetic pumping can be important during plasma startup but should be less so during the discharge flattop where strong heating is still observed. Work supported by U.S.D.O.E. and N.S.F.

10:00AM NI2.00002 Measurements and Simulations of Fluctuation-Driven Magnetic Fields in Flowing Liquid Metal , ERIK SPENCE, ETH Zurich — The Madison Dynamo Experiment is designed to self-generate magnetic fields from flows of liquid sodium in a simply-connected spherical geometry. A velocity field is produced in the experiment by two counter-rotating impellers. The flow is very turbulent, with a fluid Reynolds number greater than 10^6. The role of turbulent velocity and magnetic field fluctuations in magnetic field generation is explored by applying an external magnetic field to the flowing sodium, and measuring the resulting magnetic field. An external dipole moment is measured which the mean axisymmetric velocity field is incapable of generating. Since the external induced magnetic field is axisymmetric, the dipole moment must be generated by fluctuations. The experimental approach to understanding these fluctuations involves measurement of the axisymmetric magnetic field in the sodium experiment, measurement of the velocity field in a dimensionally identical water experiment, and the calculation of the axisymmetric magnetic fields induced by both the mean flow and by fluctuations. The presence of a strong diamagnetic field, generated by fluctuations, is identified and its spatial structure presented. Such a fluctuation-driven magnetic field is also found in simulations of the experiment, which are used to elucidate the nature of the fluctuations, and how they induce the diamagnetic field.

10:30AM NI2.00003 A Fully-Relaxed Helicity Balance Model for the HIT-SI Spheromak , R.G. O'NEILL, University of Washington — A fully relaxed Taylor-state model is shown to agree with HIT-SI surface and internal magnetic profile measurements. Helicity balance predicts the peak magnitude of toroidal spheromak current and the threshold for spheromak formation. The model also accurately predicts the division of the applied injector loop voltage between the injector and spheromak regions. The Taylor state for HIT-SI can be thought of as a linear superposition of three Taylor states: One for each injector with the injector flux as a boundary condition, and one for the spheromak equilibrium itself. [T.R. Jarboe, W.T. Hamp, G.J. Marklin, B.A. Nelson, R.G. O'Neill, A.J. Redd, P.E. Sieck, R.J. Smith, and J.S. Wrobel, *Phys. Rev. Lett.*, v 97, p 115003, (2006)] The Taylor states are calculated directly from the machine geometry, and the magnitudes of the injector states are determined by the measured injector currents. Both the surface fields and internal field profile agree to within 10% of the fields measured in the experiment, using only the spheromak current as the fitting parameter. By assuming helicity is injected at a rate 2VΨ, and only decays through resistivity the equilibrium is predicted with no fitting parameters, demonstrating helicity balance in a sustained spheromak for the first time without the large uncertainty of sheath drops. Spitzer resistivity (using Z=2) is assumed with the electron temperature measured by Langmuir probe. Although the experimental results suggest a higher effective resistivity by a factor of 1.5 compared to the Spitzer value the prediction is still within the uncertainties in the measured parameters. The voltage division between injector and spheromak regions is measured with internal electrostatic probes and agrees with the model to within 20%. HIT-SI produces 1 m diameter spheromaks with toroidal currents of up to 30 kA. FIR density data will also be presented.

11:00AM NI2.00004 Modeling Nuclear Fusion with an Ultracold Nonneutral Plasma[1] , DANIEL H.E. DUBIN, Univ. of California, San Diego — In the hot dense interiors of stars and giant planets, nuclear fusion reactions are predicted to occur at rates that are greatly enhanced compared to rates at low densities. The enhancement is caused by plasma screening of the repulsive Coulomb potential between nuclei, which increases the probability of the close collisions that are responsible for fusion.[2] This screening enhancement is a small but measurable effect in the Sun;[3] and is predicted to be much larger in dense objects such as white dwarf stars and giant planet interiors where the plasma is strongly coupled (i.e., where the Debye screening length is smaller than the mean interparticle spacing). However, these strongly enhanced fusion reaction rates have never been definitively observed in the laboratory. This talk discusses a method for observing the enhancement using an analogy between nuclear energy and cyclotron energy in a cold nonneutral plasma in a strong magnetic field. In such a plasma, the cyclotron frequency is higher than other dynamical frequencies, so the kinetic energy of cyclotron motion is an adiabatic invariant. This energy is not shared with other degrees of freedom except through close collisions that break the invariant and couple the cyclotron motion to the other degrees of freedom. Thus, the cyclotron energy of an ion, like nuclear energy, can be considered to be an internal degree of freedom that is accessible only via close collisions. Furthermore, the rate of release of cyclotron energy is enhanced through plasma screening by precisely the same factor as that for the release of nuclear energy, because both processes rely on the same plasma screening of close collisions.[4] Simulations and experiments measuring large screening enhancements in strongly-coupled plasmas will be discussed, along with the possibility of exciting and studying "burn fronts."

[1]Supported by NSF/DOE grant PHY-0613740 and NSF grant PHY-0354979.

[2]E. E. Salpeter and H. van Horn, *Astrophys. J.* **155**, 183 (1969).

[3]J. N. Bachall L.S.Brown, A.Gruzinov, and R. F. Sawyer., *A&A* **383**, 291-295 (2002).

[4]D. Dubin, *Phys. Rev. Lett.* **94**, 025002 (2005); M. J. Jensen, T. Hasegawa, J. J. Bollinger, and D.H.E. Dubin, *Phys. Rev. Lett.* **94**, 025001 (2005).

11:30AM NI2.00005 Coulomb crystallization in classical and quantum systems[1] , MICHAEL BONITZ, Institute for Theoretical Physics and Astrophysics, Kiel University, Germany — Coulomb crystallization occurs in one-component plasmas when the average interaction energy exceeds the kinetic energy by about two orders of magnitude. A simple road to reach such strong coupling consists in using external confinement potentials the strength of which controls the density. This has been succsessfully realized with ions in traps and storage rings and also in dusty plasma. Recently a three-dimensional spherical confinement could be created [1] which allows to produce spherical dust crystals containing concentric shells. I will give an overview on our recent results for these "Yukawa balls" and compare them to experiments. The shell structure of these systems can be very well explained by using an isotropic statically screened pair interaction. Further, the thermodynamic properties of these systems, such as the radial density distribution are discussed based on an analytical theory [3]. I then will discuss Coulomb crystallization in trapped quantum systems, such as mesoscopic electron and electron hole plasmas in coupled layers [4,5]. These systems show a very rich correlation behavior, including liquid and solid like states and bound states (excitons, biexcitons) and their crystals. On the other hand, also collective quantum and spin effects are observed, including Bose-Einstein condensation and superfluidity of bound electron-hole pairs [4]. Finally, I consider Coulomb crystallization in two-component neutral plasmas in three dimensions. I discuss the necessary conditions for crystals of heavy charges to exist in the presence of a light component which typically is in the Fermi gas or liquid state. It can be shown that their exists a critical ratio of the masses of the species of the order of 80 [5] which is confirmed by Quantum Monte Carlo simulations [6]. Familiar examples are crystals of nuclei in the core of White dwarf stars, but the results also suggest the existence of other crystals, including proton or α-particle crystals in dense matter and of hole crystals in semiconductors.

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[2] M. Bonitz, D. Block, O. Arp, V. Golubnychiy, H. Baumgartner, P. Ludwig, A. Piel, and A. Filinov, Phys. Rev. Lett. **96**, 075001 (2006).
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[1]Supported by Deutsche Forschungsgemeinschaft via SFB-TR 24.

12:00PM NI2.00006 Neutral depletion and transport in low temperature plasmas , AMNON FRUCHTMAN[1], Holon Institute of Technology — Space and laboratory plasmas can be dramatically affected by neutral depletion. We describe the effect of neutral depletion on low temperature laboratory plasmas in which the plasma is either collisional or collisionless and neutrals are either thermalized or move ballistically. In all these cases the total number of neutrals is shown to be the similarity variable that determines the electron temperature. For collisional plasma that is in pressure balance with the neutral gas it has been shown that because of the inherent coupling of ionization and transport, an increase of the energy invested in ionization can nonlinearly enhance the transport process. Such an enhancement of the plasma transport due to neutral depletion was shown to result in an unexpected *decrease* of the plasma density when power is *increased;* despite the *increase* of the flux of generated plasma.[1] Unexpected steady-state has also been found for collisionless plasma due to neutral depletion. For ballistically-moving neutral-gas the strong ionization results in an expected neutral-gas minimum at the center of the chamber.[2] However, Raimbault *et al.* have shown that in the case of thermalized neutral-gas (in which the pressure increases with density) a strong ionization results in a maximum of the neutral-gas density surprisingly located at the center of the chamber.[3] The effects of neutral depletion due to a noticeable neutral gas heating will also be discussed. When collisions with electrons are the dominant source of neutral heating, that heating is larger at the center of the discharge,[4] while when collisions with ions are the dominant source, the heating is larger near the wall. It will be shown that, interestingly, the partitioning of power between plasma and neutral-gas is a function of the electron temperature only and not of the power level.

1. A. Fruchtman, G. Makrinich, P. Chabert, and J.-M. Rax, Phys. Rev. Lett. **95,** 115002 (2005).

2. A. Fruchtman, "Neutral depletion and pressure balance in plasma", 33rd EPS Conference on Plasma Physics, Rome, 19 - 23 June 2006, ECA Vol. **30I**, D-5.013 (2006).

3. J.-L. Raimbault, L. Liard, J.-M. Rax, P. Chabert, A. Fruchtman, and G. Makrinich, Phys. Plasmas **14**, 013503 (2007).

4. L. Liard, J.-L. Raimbault, J.-M. Rax, and P. Chabert, "Plasma transport under neutral gas depletion conditions", submitted to J. Phys. D.

[1]In collaboration with G. Makrinich, L. Liard, J.-L. Raimbault, P. Chabert, and J.-M. Rax

Wednesday, November 14, 2007 9:30AM - 12:06PM –
Session NO3 Simulation and Modeling Rosen Centre Hotel Salon 9/10

9:30AM NO3.00001 Simulation of plasma effects on rf power transport in vacuum waveguides[1]

, PETER STOLTZ, DAVID SMITHE, Tech-X Corporation — Researchers use rf power to heat tokamak plasmas and excite cavities for particle accelerators among other applications. Unwanted plasma can limit the power one can transmit from a source (such as a klystron) to the target (such as the tokamak plasma or the accelerating cavity). Researchers believe some possible sources for this plasma are ionization of residual gas or sputtering of material from the waveguide surface. We use computer simulation to model the effects of this plasma on the rf power transmission in a typical rf waveguide. In particular, we estimate using a coronal model the power radiated by ions in the plasma (these could be plasma ions or impurity ions). We calculate the ion density required to radiate all the incident rf power for various power levels up to 100 MW. We also use this density to estimate spot sizes on the waveguide surface, comparing these estimates with observations at the Stanford Linear Accelerator Center.

[1]DoE OFES through the SBIR program.

9:42AM NO3.00002 Grid-Free Particle Method for Electrostatic Plasmas[1]

, ROBERT KRASNY, LYUDMYLA BARANNYK[2], University of Michigan, BENJAMIN SONDAY, Princeton University, ANDREW CHRISTLIEB, JINGMEI QIU, Michigan State University — A grid-free particle method for electrostatic plasmas is presented. The method is based on the Lagrangian formulation of the Vlasov-Poisson equations in terms of the flow map of the charge distribution. We employ several numerical techniques including: (1) regularizing the Coulomb singularity, (2) adaptive particle insertion, and (3) a treecode algorithm to accelerate the evaluation of the electric field. Simulations are presented for the instability of collisionless electron beams.

[1]Supported by AFOSR
[2](current affiliation: University of Idaho)

9:54AM NO3.00003 Correlated Relativistic Current Sheet Systems

, CLAUS JAROSCHEK, MASAHIRO HOSHINO, The University of Tokyo — We study the non-linear evolution of interacting Relativistic Current Sheets (RCS) in 1D/2D/3D self-consistent kinetic plasma simulations within the framework of the Particle-In-Cell model. The intention is to extend the existing knowledge about individual RCS in pair plasma - where the physics is determined by the relativistic tearing and drift kink modes as competing RCS instabilities - towards a correlated RCS system. Such RCS systems are the key element of generic 'striped wind' configurations proposed to model relativistic plasma flows like pulsar winds and gamma-ray bursts. Interactions are enforced in head-on collisions of systems consisting of up to ten individual and equi-distantly separated RCS. The global dynamics divides into a weakly and strongly correlated regime. In the weakly correlated case each RCS persists as an entity and non-thermal particle generation is attributed to a stochastic Fermi-type acceleration mechanism. In the complementary strongly correlated regime the RCS interpenetrate thouroughly and efficient magnetic field dissipation is observed within a 1D stratification. Localized regions persist where the electric supersedes the magnetic field, i.e. the transformation of particle orbits towards a de Hoffmann-Teller-frame is then inherently impossible.

10:06AM NO3.00004 The Equilibrium Ensemble of Three-dimensional Hall Magnetohydrodynamics

, SERGIO SERVIDIO, WILLIAM MATTHAEUS, Bartol Research Institute, University of Delaware, Newark, DE 19716, VINCENZO CARBONE, Dipartimento di Fisica, Unita' di Cosenza, Ponte Pietro Bucci, Cubo 31C, 87036 Rende (CS), Italy — The nonlinear dynamics of ideal and incompressible Hall Magnetohydrodynamics (HMHD) is investigated through classical Gibbs ensemble methods. The spectral structure of the HMHD is derived in a three dimensional periodic geometry and then compared with the MHD case. The purpose of the work is to provide a general picture of Hall MHD spectral transfers and cascades by the assumption that it follows equilibrium statistics. In the HMHD case the equilibrium ensemble is built on the conservation of three quadratic invariants, that is the total energy, the magnetic helicity, and the hybrid helicity. The latter replace the cross helicity in the one fluid case. In the HMHD equilibrium a tendency to have double cascade (inverse and direct) is observed, moreover the Alfven effect (dynamical alignment between velocity and magnetic field) is broken at ion skin depth scales. The ensemble predictions are compared to numerical simulations with a low order truncation Galerkin spectral code.

10:18AM NO3.00005 Vlasov-Fokker-Planck Transport Simulations Of Magnetic Field Instabilities

, ALEXANDER THOMAS, Imperial College, CHRISTOPHER RIDGERS, ROBERT KINGHAM — Strong magnetic fields are well known to significantly affect the transport properties of plasmas. In addition to being externally applied, these can be self-generated spontaneously through non-linear processes. Magnetic field generating instabilities include thermomagnetic and pressure anisotropy (e.g. Weibel) effects. These are best described by the Vlasov-Fokker-Planck equation, in the presence of strong gradients where non-local effects are important, as is usually the case in laser-plasma interactions. We have further developed the 2-D Vlasov-Fokker-Planck code IMPACT to include terms in the cartesian tensor expansion of velocity space up to order 3. The previous code included only zero and first order terms, which are not sufficient to completely describe some of these magnetic instabilities. Analytic and numerical modeling of the semi-collisional regime of magnetic field generation is presented, which demonstrate spontaneous growth of magnetic fields and the effect of adding these higher order terms. We consider the ramifications of these for inertial fusion energy.

10:30AM NO3.00006 Plasma microturbulence with dual drive

, F. MERZ, M. KAMMERER, F. JENKO — Turbulence driven by ITG modes and trapped electron modes (TEMs) is generally considered the key mechanism for anomalous transport in fusion devices on ion scales. But while there exist many theoretical studies of pure ITG turbulence, not much is presently known about the properties of pure TEM turbulence and about possible nonlinear interactions between ITG modes and TEMs. These important questions will be addressed here by means of nonlinear gyrokinetic simulations with the GENE code. We find that temperature gradient driven TEM turbulence – in contrast to ITG turbulence – does not saturate via zonal flow generation. Instead, the transport dominating modes in the k_y spectrum largely resemble the respective linear microinstabilities, and the action of the nonlinearity on long-wavelength TEMs is statistically equivalent to that of a diffusion operator. This is the basis for a rather simple transport model which is able to capture many features observed in the nonlinear simulations. In order to be able to examine the coexistence of TEM and ITG instabilities in certain regions of parameter space, GENE has been extended by an eigenvalue solver which is capable of dealing with the very large matrices that occur in this context. Thus it becomes possible to detect and analyze also subdominant modes, and to relate their characteristics to those of the corresponding turbulent system. The nature of a dual turbulence drive and the consequences for transport modelling will be discussed.

10:42AM NO3.00007 ETG Modeling of a TCV Multi-Phase H-Mode Shot

, ELINA ASP, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas, Association Euratom Confederation Suisse, CH-1015 Lausanne, JUHYUNG KIM, WENDELL HORTON, Institute for Fusion Studies, University of Texas Austin, Austin, Texas 78712, US, LAURIE PORTE, STEFANO ALBERTI, EMILIANO FABLE, YVES MARTIN, OLIVIER SAUTER, GIANPAOLO TURRI, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas, Association Euratom Confederation Suisse, CH-1015 Lausanne, TCV TEAM — TCV is well suited for electron transport studies due to its well developed ECRH system. Ion heating is achieved by thermal equilibration at high density in combination with strong third harmonic X-mode (X3) ECRH heating. In TCV shot 29892, X3 heating was applied to an ohmic ELMy H-mode, either at full or modulated power. This shot covers four stationary H-mode phases, one ohmic followed by three ELMy or ELM-free X3 heated. The final two are akin to improved H-modes. Previous analysis with the GLF model implied the discharge to be ITG dominated, in accordance with a preliminary Weiland stability analysis. As the applied heating only affects the electrons it is important to analyze this discharge regarding ETG and/or TEM modes. The ETG turbulence calculated with the IFS-ETG model will be presented. This model has already successfully calculated electron transport in dominantly electron-heated NSTX and Tore Supra.

10:54AM NO3.00008 Spatio-temporal correlations in edge tokamak plasma , J. HORACEK, Institute of Plasma Physics AS CR, A.H. NIELSEN, O.E. GARCIA, Risoe National Laboratory, Denmark, R.A. PITTS, CRPP EPFL Lausanne Switzerland, CRPP EPFL LAUSANNE SWITZERLAND COLLABORATION — Plasma fluctuations in the scrape-off layer (SOL) of tokamak TCV have been investigated by means of electrostatic probes, and compared directly with two-dimensional fluid interchange turbulence simulation ESEL. This model permits electron density, temperature and vorticity (potential) to evolve freely at the outside midplane region of a tokamak. The viscosity and parallel particle loss are based on the neoclassical Pfirsch-Schlutter diffusion and classical parallel transport, respectivelly. In this contribution we focus on comparing the time-scales, spatial scales of fast fluctuations of density and temperature, using the unique tunnel probe capable of fast (1 MHz) electron temperature measurement. Significant difference in statistical behaviour of both density and temperature fluctuations between the tokamak top and the low-field side location has been found experimentally on the small tokamak CASTOR, whilst still the statistical characteristics correspond well at the low-field side with the ESEL simulations. This further confirms dominance of the interchange turbulence at the low-field side, where the observed bursty events are generally attributed to the radial motion of blob-like structures through the SOL.

11:06AM NO3.00009 Edge kinetic-MHD code coupling and monitoring with Kepler workflow , JULIAN CUMMINGS, Caltech, SCOTT KLASKY, ROSELYNE BARRETO, ORNL, NORBERT PODHORSZKI, UC Davis, GUNYOUNG PARK, C.S. CHANG, NYU, LINDA SUGIYAMA, MIT, PHIL SNYDER, General Atomics, CENTER FOR PLASMA EDGE SIMULATION TEAM — Simulations of edge pressure pedestal buildup and ELM crash in a typical DIII-D H-mode discharge are performed using Kepler, an open-source scientific workflow system that manages complex applications. A Kepler workflow conducts an edge plasma simulation that loosely couples the kinetic code XGC0 with an ideal MHD linear stability analysis code ELITE and a two-fluid MHD initial value code M3D. XGC0 simulation data are processed by the workflow into simple graphs that may be selectively displayed via the Dashboard, a monitoring tool that allows real-time data tracking within a standard Web browser. Kepler runs ELITE to assess plasma profiles from XGC0 for linear ELM instability. If unstable, Kepler launches M3D to simulate the nonlinear ELM crash. Periodic outputs of plasma fluid quantities are automatically imaged and may be displayed on the Dashboard. Finally, Kepler archives all simulation output, processed images, and provenance tracking data. Preparation, execution, and monitoring of this coupled-code simulation using the Kepler scientific workflow system are described.

11:18AM NO3.00010 Noise control in global gyrokinetic particle simulations , BEN MCMILLAN, SEBASTIEN JOLLIET, PAOLO ANGELINO, TRACH-MINH TRAN, LAURENT VILLARD, Ecole Polytechnique Federale de Lausanne (EPFL), Centre de Recherches en Physique des Plasmas, Association Euratom-Suisse, ALBERTO BOTTINO, Max Planck Institut fur Plasmaphysik, IPP-EURATOM Association, Garching — The use of gyrokinetic PIC codes for long simulations is hindered by the accumulation of noise: we explore the use of a relaxation operator to prevent this noise accumulation. The simplest relaxation operator is the Krook operator, which acts somewhat like an artificial collisionality, and can effectively control noise; it also introduces an unphysical dissipation, which may damp persistent structures like zonal flows and significantly modify simulation results even when the relaxation time is very long. We describe a method for projecting out the effects of the Krook operator on the zonal flows, and use this in the ORB5 gyrokinetic code [1], thereby preventing the secular accumulation of noise without introducing a large inaccuracy in the model. The results of the simulations are consistent with previous studies. Numerical efficiency is greatly improved due to the smaller number of markers required per mode compared to long simulations without a relaxation operator.

[1] S. Jolliet *et al.*, to appear in Comput. Phys. Commun.

11:30AM NO3.00011 Gyrokinetic simulations of electron density fluctuations and comparisons with measurement , R.V. BUDNY, E. MAZZUCATO, PPPL, A. FONSECA, CFN-IST, R. BRAVENEC, Univ. Texas, Austin, J. CANDY, R.E. WALTZ, GA, TFTR TEAM, EFDA-JET COLLABORATION — Understanding transport is important for creating reliable predictions of plasma performance in fusion reactors. Plasma turbulence causes much of the transport seen in present experiments. Gyrokinetic codes can simulate turbulence and turbulent-driven transport. Further verifying and validating these simulations are needed. One class of tests is provided by electron density fluctuation $\tilde{n}_e$ measurements using techniques such as reflectometry and beam-emission-spectroscopy. The GYRO gyrokinetic code is being used to simulate turbulence and turbulent-driven energy, angular momentum, and species flows in experiments. GYRO can generate the time-evolving fluctuations of $\tilde{n}_e$ in three spatial dimensions. From this, profiles, along the diagnostic lines-of-sight, of the root-mean-square $\tilde{n}_e$, radial correlation lengths λ_r, and power spectra can be produced. This paper compares on GYRO simulations of reflectometry measurements in TFTR D and DT supershots and JET. Three kinetic species (2 ions and electrons) are assumed, about half the plasma radius is simulated. Realistic geometry and electron-ion collisions are included. Agreement to within about a factor of two is achieved.

11:42AM NO3.00012 Gyrokinetic Simulation of Trapped Electron Mode Turbulence , YONG XIAO, ZHIHONG LIN, University of California, Irvine — Trapped electron mode (TEM) has long been considered as an important candidate to account for the anomalous transport in the core plasma. Global gyrokinetic particle simulation using the GTC code finds that the trapped electron mode (TEM) can be driven unstable by steep density gradient. Gyrokinetic particle simulation shows that in TEM turbulence trapped electrons can drive larger heat transport that ions. A second busty phenomenon is observed, which differs from its ITG counter part. It is also found that zonal flow plays an important role in regulating TEM turbulence with the current parameters, as it does for ITG turbulence.

11:54AM NO3.00013 Instability modeling of homogenous and inhomogeneous plasmas using nonparametric distribution estimation and convex vector optimization algorithms , SAM ADHIKARI, Sysoft, R&D Division of Integratsie Inc. — Due to departure from thermodynamic equilibrium, plasma instabilities are difficult to model. Velocity distributions in homogenous plasma and associated kinetic energies are modeled and simulated using nonparametric distribution estimation algorithms. The magnetic field and the spatial inhomogeneities for inhomogeneous plasmas are also modeled using vector optimization algorithms. Bounding probabilities and expected values provide excellent results for homogenous plasmas. Scalarization algorithms for Pareto optimization in inhomogenous plasmas are used. The problem eventually turns into a multicriterion vector optimization problem.

Wednesday, November 14, 2007 9:30AM - 12:18PM –

Session NO6 Laser-Plasma Coupling at Long Scale Length Rosen Centre Hotel Salon 5/6

9:30AM NO6.00001 LPI Risk Mitigation on NIF Using Larger Radius Hohlraums , PAUL BRADLEY, D.C. WILSON, Los Alamos National Laboratory, D. CALLAHAN, L.J. SUTER, M.J. EDWARDS, Lawrence Livermore National Laboratory — As part of the laser-plasma instability (LPI) risk mitigation strategy for ignition at the National Ignition Facility, we performed capsule/hohlraum calculations where we made the hohlraum 20% larger in radius than a standard 300 eV design. The hope is the larger radius would reduce the plasma electron density and thereby reduce the LPI gains to an acceptable level. We find that although the electron density is lower, this is offset by by the increased intensity needed to heat the larger hohlraum, so there is little improvement in the LPI gains. Also, relatively more power is required in the outer cone in order to obtain an implosion symmetry good enough for ignition in our calculations. There appears to be little advantage to making the hohlraum larger in radius without taking additional steps to mitigate LPI gain. Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

9:42AM NO6.00002 An Assessment of Laser-Plasma Instabilities in NIF Ignition Hohlraums with Different Capsule Ablators.[1] , R.P.J. TOWN, D.A. CALLAHAN, L. DIVOL, M.J. EDWARDS, S.W. HAAN, D.E. HINKEL, D.D. HO, O.S. JONES, P. MICHEL, L.J. SUTER, E.A. WILLIAMS, Lawrence Livermore National Laboratory, Livermore, CA — The NIF ignition point design uses a cryogenic DT fuel enclosed within a copper-doped beryllium ablator. The capsule is placed in a gold-uranium cocktail hohlraum driven to a peak drive temperature of 285eV. As part of a system optimization study we are examining two alternative ablator materials: high-density carbon, and germanium-doped plastic. High-density carbon, for a given capsule size, absorbs most x-ray energy. Changing the ablator material alters the plasma conditions inside the hohlraum, consequently modifying the laser-plasma interactions (LPI). We report on LASNEX simulations of hohlraums with these three ablator materials, quantifying the bulk plasma conditions, and use them to estimate the relative risk for LPI.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

9:54AM NO6.00003 Modeling energy transfer via beam crossing in NIF hohlraums[1] , PIERRE MICHEL, LAURENT DIVOL, ED WILLIAMS, DEBBIE CALLAHAN, LLNL — The interference between two laser beams crossing in a plasma can efficiently excite an ion acoustic wave, which can drive forward Stimulated Brillouin Scattering between the beams and transfer energy from one to the other. In NIF, multiple beams will cross at the laser entrance hole of the hohlraum. The energy transfer may affect symmetry, but can be controlled through a planned tuning of the frequencies of the beams. We used our paraxial laser-plasma interaction code SLIP to study the energy transfer between laser beams for typical NIF target designs. SLIP uses a linear kinetic coupling between the laser beams and the ion acoustic wave. We will present results on the typical energy transfer between NIF beams, and on the optimum set of parameters that minimize the transfer and optimizes symmetry.

[1]This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

10:06AM NO6.00004 Hohlraum Hot-Electron Production , S.P. REGAN, T.C. SANGSTER, D.D. MEYERHOFER, W. SEKA, B. YAAKOBI, R.L. MCCRORY, C. STOECKL, V.YU. GLEBOV, Laboratory for Laser Energetics, U. of Rochester, N.B. MEEZAN, W.L. KRUER, L.J. SUTER, E.A. WILLIAMS, O.S. JONES, D.A. CALLAHAN, M.D. ROSEN, O.L. LANDEN, S.H. GLENZER, C. SORCE, B.J. MACGOWAN, LLNL — The coupling of laser energy into hot e^-'s was investigated for Au hohlraums on OMEGA using the hard-x-ray diagnostic. Forty beams smoothed with phase plates and arranged in three cones irradiated vacuum, SiO_2-lined, and gas-filled targets with a 14-kJ PS26 pulse shape. Two bursts of x rays were observed from gas-filled hohlraums. The first ($T_h \sim$ 100 keV) occurs as the LEH window explodes and is likely generated by the $2\omega_{pe}$ instability or by cooperatively driven SRS. The second ($T_h \sim$ 50 keV) coincides with SRS during the main drive. The hot e^- coupling increased with n_e from 2 to 9 $\times$ 10^{20}cm^{-3} and increases during the main drive of a CH-lined LEH hohlraum if $n_e \leq 4 \times 10^{20}$ cm^{-3}, where n_e is the initial n_e of the fully ionized gas fill. Vacuum and SiO_2-lined targets (no LEH window) had a lower-level, single-x-ray burst during the main drive. Quantitative coupling estimates will be given. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460.

10:18AM NO6.00005 Simulations of gas-filled hohlraum targets on the OMEGA laser[1] , N.B. MEEZAN, D.J. STROZZI, R.E. TURNER, K. WIDMANN, E.A. WILLIAMS, L.J. SUTER, Lawrence Livermore National Laboratory, S.P. REGAN, Laboratory for Laser Energetics, University of Rochester — Recent experiments on the OMEGA laser facility examined x-ray drive and hot-electron generation in gold hohlraums filled with CH gas mixtures of varying densities. Some hohlraums also had CH-lined laser entrance holes. Radiation-hydrodynamics simulations using the code HYDRA show that early-time hot electrons likely originated in the blast-wave driven by the explosion of the hohlraum windows. Hot electrons also occurred during the main drive as the hohlraum bulk plasma approached $n_e = 0.25n_c$. The plasma waves that generate hot electrons can be driven by Stimulated Raman Scattering (SRS) or by the two-plasmon decay instability. Comparisons between simulations and SRS backscatter data can help determine the source of the hot electrons. These results can inform the design of the laser pulse for NIF ignition hohlraums.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

10:30AM NO6.00006 Kinetic modeling of Raman scattering with adiabatic electron response[1] , DAVID J. STROZZI, Lawrence Livermore National Lab (LLNL), DIDIER BÉNISTI, LAURENT GREMILLET, CEA/DAM, Bruyères-Le-Châtel, France — Nonlinearity due to electron trapping in stimulated Raman scattering (SRS) has been studied analytically and via 1-D Vlasov simulations with the ELVIS code. The adiabatic calculation of the electron susceptibility χ [D. Bénisti, L. Gremillet, Phys. Plasmas **14**, 042304 (2007)] has been used to derive the dispersion relation of an SRS-driven plasma wave (from Re[χ]), and an envelope equation (from Im[χ]). Unlike earlier theories, this dispersion relation reflects both that the wave is driven, and that its phase velocity depends on amplitude. The theory agrees well with the frequency measured in simulations. The driven nature of the plasma wave initially produces a large frequency shift, after which the nonlinearity in Re[χ] dominates. The overall downshift exceeds classical formulas (e.g. Morales and O'Neil) when $k\lambda_{De} >$ 0.35. Moreover, the frequency **and wave number** of the scattered light wave both vary with amplitude, keeping SRS closer to resonance than it would be if only the frequency varied. The detrapping of electrons when the wave amplitude decreases may give electrostatic turbulence: the distribution increases for some velocities above that of the SRS plasma wave.

[1]Work at LLNL performed under US DoE Contract W-7405-Eng-48.

10:42AM NO6.00007 Saturation of Backward Stimulated Scattering of Laser in Kinetic Regime , L. YIN, B.J. ALBRIGHT, K.J. BOWERS, W. DAUGHTON, H.A. ROSE, Los Alamos National Laboratory — Stimulated Raman (SRS) and Brillouin scattering (SBS) are examined in the kinetic regime using particle-in-cell simulations. Wavefront bowing of electron plasma waves (ion-acoustic wave) due to the trapped particle nonlinear frequency shift is observed in the SRS (SBS) regime for the first time, which increases with laser intensity. Self-focusing from trapped particle modulational instability (TPMI) [H. A. Rose, Phys. Plasmas, **12**, 12318, 2005] is shown to occur in both 2D and 3D SRS simulations. The key physics of SRS saturation is identified as a combination of wavefront bowing, TPMI and self-focusing: Bowing marks the beginning of SRS saturation and self-focusing terminates the SRS pulse, both effects resulting from cancellation of the source term for SRS. Ion acoustic wave bowing also contributes to SBS saturation. Velocity diffusion by transverse modes and rapid loss of hot electrons in regions of small transverse extent formed from self-focusing dissipate the wave energy and increase Landau damping in spite of strong electron trapping that reduces Landau damping initially. The ranges of wavelength and growth rate associated with transverse break-up of the electron plasma waves are also examined in 2D speckle simulations as well as in 2D periodic systems from BGK equilibrium and are compared with theory predictions.

10:54AM NO6.00008 Saturation of Stimulated Raman Scatter in laser speckle by Langmuir wave self-localization , HARVEY ROSE, L. YIN, LANL — Since the trapped electron Langmuir wave (LW) frequency shift, $\delta\omega < 0$ exceeds [1] the frequency shift due to ponderomotive expulsion of plasma density for LW wavenumber $k\lambda_D > 0.2$, self-localization effects induced by trapped electrons are dominant for short times in hot, under dense, plasma. For SRS originating in laser speckles, with daughter LW wavenumber in an intermediate wavenumber regime, k=0.35, we show from both 2D PIC simulations and reduced model calculations that $\delta\omega$ leads to LW phase front bowing whose curvature increases with wave amplitude, ϕ, and time. Once the bow radius of curvature is smaller than a speckle width, the SRS source oscillates in sign across the speckle, causing SRS saturation. This process is neither unstable nor strongly dissipative: results show reduction of SRS even while LW energy grows. However, as ϕ continues to grow and the trapped electron LW self-focusing threshold exceeded, the LW breaks into filaments [2], causing enhanced rate of loss of trapped electrons and associated increase of Landau damping, followed by rapid demise of the SRS pulse.

[1] Harvey A. Rose, Physics of Plasmas **12**, 012318 (2005)
[2] L. Yin, et al., Physics of Plasmas 13, 072701, (2006).

11:06AM NO6.00009 Scattered-Laser-Light Spectroscopy in Direct-Drive Implosion Experiments , D.H. EDGELL, W. SEKA, J.A. DELETTREZ, R.S. CRAXTON, V.N. GONCHAROV, I.V. IGUMENSHCHEV, J. MYATT, A.V. MAXIMOV, R.W. SHORT, T.C. SANGSTER, R.E. BAHR, Laboratory for Laser Energetics, U. of Rochester — The time-dependent laser absorption during spherical direct-drive implosions on OMEGA is inferred from scattered-light spectroscopy. We compare measured spectral shifts for different pulse shapes with the shifts predicted using a hydrodynamic code. The predictions vary dramatically with the electron-heat-conduction model. A nonlocal transport model provides the best match to the measurements. The modeling calculates the "blow-by" signal from the beam opposite the detector, improving the measurements of total scattered light. Remaining spectral discrepancies suggest nonlinear energy exchange between crossed beams due to stimulated Brillouin scattering. Analogous planar experiments test this hypothesis. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

11:18AM NO6.00010 Two-Plasmon-Decay Instability Driven by Incoherent Laser Irradiation , A.V. MAXIMOV, J. MYATT, R.W. SHORT, W. SEKA, C. STOECKL, Laboratory for Laser Energetics, U. of Rochester — Two-plasmon-decay (TPD) instability is an important source of hot electrons observed in direct-drive inertial confinement fusion experiments on the OMEGA Laser System.[1] A model for the TPD instability driven by incoherent laser beams in inhomogeneous plasmas has been developed that modifies the results of the three-wave TPD model[2] for the instability thresholds. The influence of low-frequency plasma perturbations caused by the beating of electromagnetic and plasma waves on TPD through the modification of the density profile is considered. The developed TPD model is applied for conditions typical of the experiments on OMEGA. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] C. Stoeckl *et al.*, Phys. Rev. Lett. **90**, 235002 (2003).
[2] A. Simon *et al.*, Phys. Fluids **26**, 3107 (1983).

11:30AM NO6.00011 White light Parametric Instabilities , L. SILVA, GoLP — Different techniques capable of describing the propagation and modulation instability of partially coherent/incoherent "white" light in nonlinear media are based on the paraxial wave approximation. In general, this approach is not valid for instabilities associated with the partially reflected backscattered radiation critical in many laser-plasma scenarios, such as ICF or fast ignition, and astrophysical scenarios. Inclusion of bandwidth/incoherence effects in laser driven parametric instabilities in plasmas can be described, for forward scattering by the standard Wigner-Moyal formalism, or by a generalized Wigner-Moyal statistical theory of radiation, or generalized photon kinetics, formally equivalent to the full wave equation, valid for partially coherent electromagnetic wave propagation in nonlinear dispersive and diffractive media. With this approach a generalized dispersion relation for Stimulated Raman Scattering driven by a partially coherent pump field has been derived, revealing a marked difference between backscattering (three-wave process), and direct forward scattering (four-wave process). This qualitative difference illustrates a fundamental difference between these two processes. The results, which generalize the classic results for plane wave pumps, demonstrate the possibility to control the growth rates of these instabilities by properly using broadband pump radiation fields.

11:42AM NO6.00012 Collective stimulated Brillouin backscatter , PAVEL LUSHNIKOV, Department of Mathematics and Statistics, University of New Mexico, HARVEY ROSE, LANL — We develop the statistical theory of linear collective stimulated Brillouin backscatter (CBSBS) in spatially and temporally incoherent laser beam. Instability is collective because it does not depend on the dynamics of isolated hot spots (speckles) of laser intensity, but rather depends on averaged laser beam intensity, optic f/#, and laser coherence time, T_c. CBSBS has a much larger threshold than a classical coherent beam's in long-scale-length high temperature plasma. It is a novel regime in which T_c is too large for applicability of well-known statistical theories (RPA) but T_c must be small enough to suppress single speckle processes such as self-focusing. Even if laser T_c is too large for *a priori* applicability of our theory, collective forward SBS[1], perhaps enhanced by high Z dopant, and its resultant self-induced T_c reduction, may regain the CBSBS regime. We identified convective and absolute CBSBS regimes. The threshold of convective instability is inside the typical parameter region of NIF designs. Well above incoherent threshold, the coherent instability growth rate is recovered. [1] P.M. Lushnikov and H.A. Rose, Plasma Physics and Controlled Fusion, 48, 1501 (2006).

11:54AM NO6.00013 Experimental demonstration of optical mitigation techniques for stimulated Brillouin Scattering in ignition relevant plasmas[1] , DUSTIN FROULA, LAURENT DIVOL, NATHAN MEEZAN, RICHARD LONDON, RICHARD BERGER, SHAM DIXIT, JAMES ROSS, PAUL NEUMAYER, RUSSEL WALLACE, LARRY SUTER, SIEGFRIED GLENZER, Lawrence Livermore National Laboratory — Inertial confinement fusion (ICF) and high energy density physics experiments require intense and energetic laser beams to propagate efficiently through long plasmas. A series of experiments performed at Omega will be presented that study the effects of SSD, polarization smoothing, and laser beam defocusing on mitigating stimulated backscatter, filamentation, and beam spray. We measure a factor of 1.8 reduction in the stimulated Brillouin scattering (SBS) when polarization smoothing is applied; no effect on the SBS is observed when up to 3 angstroms of smoothing by spectral dispersion (SSD) is applied. Furthermore, we show that the SBS reflectivity is controlled by either reducing the laser beam intensity or defocusing. The results from these experiments compare well to linear theory as modeled in 3 dimensions by pf3D.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

12:06PM NO6.00014 Design of an Experiment to Observe Laser-Plasma Interactions on NIKE[1]

, L. PHILLIPS, J. WEAVER, W. MANHEIMER, S. ZALESAK, A. SCHMITT, D. FYFE, NRL, B. AFEYAN, M. CHARBONNEAU-LEFORT, Polymath Research Inc. — Recent proposed designs (Obenschain et al., Phys. Plasmas 13 056320 (2006)) for direct-drive ICF targets for energy applications involve high implosion velocities combined with higher laser irradiances. The use of high irradiances increases the likelihood of deleterious laser plasma instabilities (LPI) that may lead, for example, to the generation of fast electrons. The proposed use of a 248 nm KrF laser to drive these targets is expected to minimize LPI; this is being studied by experiments at NRL's NIKE facility. We used a modification of the FAST code that models laser pulses with arbitrary spatial and temporal profiles to assist in designing these experiments. The goal is to design targets and pulseshapes to create plasma conditions that will produce sufficient growth of LPI to be observable on NIKE. Using, for example, a cryogenic DT target that is heated by a brief pulse and allowed to expand freely before interacting with a second, high-intensity pulse, allows the development of long scalelengths at low electron temperatures and leads to a predicted 20-efold growth in two-plasmon amplitude.

[1]This research is funded by the US DOE.

Wednesday, November 14, 2007 9:30AM - 12:30PM –

Session NO7 Coherent and Incoherent Radiation Sources Rosen Centre Hotel Salon 7/8

9:30AM NO7.00001 Investigation of Improved Magnetron Characteristics with Transparent Cathode

, SARITA PRASAD, HERMAN BOSMAN, MIKHAIL FUKS, EDL SCHAMILOGLU, Department of Electrical and Computer Engineering, University of New Mexico, Albuquerque, NM 87101, U.S.A. — In [1] we showed: (a) fast start and rate of build-up of oscillations, (b) magnetron operation in the stable 2pi mode over a wide range of magnetic field, and (c) very high output power levels ($\sim$ 1GW), when the transparent cathode was used. This work is an attempt to explain the reasons for improvement of the magnetron characteristics in terms of priming and/or the large amplitude of the azimuthal component of the RF electric field in the electron flow region. Different cathode designs were studied in computer simulations to investigate these two effects.
[1] H. Bosman et al. IEEE Trans. Plasma Sci, 34 (4), 606 (2006).

9:42AM NO7.00002 Dielectric window breakdown in oxygen gas: from vacuum multipactor to collisional microwave discharge[1]

, S.K. NAM, C. LIM, J.P. VERBONCOEUR, University of California, Berkeley, H.C. KIM, University of Science and Technology, Y.Y. LAU, University of Michigan — The major limiting factor in the transmission of high power microwave is dielectric window breakdown. Using a PIC/MCC model, dielectric window breakdown from vacuum multipactor to collisional microwave discharge in noble gases has been investigated [1]. In contrast with noble gases, however, the oxygen in air produces negative ions, which can reach five or more times the electron density with a strong impact on the breakdown. In this work, breakdown of a dielectric window in contact with oxygen gas is investigated over a wide pressure range, and extension of the theoretical scaling law for breakdown in noble gases [2] is sought for oxygen and air.
[1] H.C. Kim *et al.*, *Phys. Plasmas* **13**, 123506 (2006).
[2] Y.Y. Lau *et al.*, *Appl. Phys. Lett.* **89**, 261501 (2006).

[1]This work was supported by AFOSR Cathode and Breakdown MURI04 Grant No. FA9550-04-1-0369, AFOSR STTR Contract No. FA9550-04-C-0069, and the Air Force Research Laboratory, Kirtland AFB.

9:54AM NO7.00003 Fast Opening Microwave Barrier and Independency of Polarization in Plasma tubes

, TED ANDERSON, IGOR ALEXEFF, University of Tennessee, and Haleakala Research and Development, Inc., ESMAEIL FARSHI, University of Tennessee, Haleakala Research and Development, Inc., FRED DYER, JEFFRY PECK, Impeccable Instruments, ERIC P. PRADEEP, NANDITHA PULSANI, NARESH KARNAM, UNIVERSITY OF TENNESSEE COLLABORATION, HALEAKALA RESEARCH AND DEVELOPMENT, INC. COLLABORATION, IMPECCABLE INSTRUMENTS COLLABORATION — Plasma barriers are used to protect sensitive microwave apparatus from potentially damaging electronic warfare signals. We have found both experimentally and theoretically that we can open such a barrier on a time scale of microseconds instead of typically many milliseconds. We do this by increasing the plasma density rather than waiting for it to decay. We produce a standing wave between the two layers that results in microwave transmission, analogous to the transmission found in an optical Fabry-Perot Resonator. The plasma tubes work extremely well in intercepting microwave radiation when the incident wave electric field is parallel to the tubes. However, if the electric field is perpendicular to the tubes, the normally induced plasma current cannot flow, and the plasma effects are not expected to appear. To our surprise, when the plasma tubes were experimentally tested with the electric field perpendicular to the tubes, the plasma tubes not only intercepted the microwave signal, but the observed cut-off with a pulsed plasma lasted about twice as long. The effect appears to be due to an electrostatic resonance, and preliminary calculations suggest that a normally ignored term in Maxwell's Equations is responsible.

10:06AM NO7.00004 Interpretation of the nonlinear mode excitation in the ITER gyrotron.[1]

, OLEKSANDR SINITSYN, GREGORY NUSINOVICH, IREAP, University of Maryland — Recently, the first 170 GHz gyrotron delivering 1 MW continuous-wave power (CW) for the International Thermonuclear Experimental Reactor (ITER) has been developed at the Japan Atomic Energy Agency (JAEA) [K. Sakamoto et al., "Achievement of robust high-efficiency 1 MW oscillation in the hard self-excitation region by a 170 GHz continuous wave gyrotron," Nature Physics, vol. 3, pp. 411- 414, 2007]. In that work the hysteresis phenomenon in excitation of two modes was described. It was found that the operating mode can be excited in the region of hard self-excitation when the parasitic mode is present. The interpretation of this effect is given in the present paper.

[1]This work is supported by the Office of Fusion Science of the US Department of Energy.

10:18AM NO7.00005 Mode switching in a gyrotron with azimuthally corrugated resonator[1]

, GREGORY NUSINOVICH, OLEKSANDR SINITSYN, THOMAS ANTONSEN, IREAP, University of Maryland — Operation of a gyrotron having a cylindrical resonator with an azimuthally corrugated wall is analyzed. In such device, wall corrugation cancels degeneracy of modes with azimuthally standing patterns. The coupling between these modes depends on the radius of electron beam. It is shown that such gyrotron can be easily switched from one mode to another. When the switching is done with the repetition frequency equal to the rotational frequency of magnetic islands, this sort of operation can be used for suppression of neoclassical tearing modes in large-scale tokamaks and stellarators.

[1]The work is supported by the Office of Fusion Science of the US Department of Energy

10:30AM NO7.00006 Propagation of cyclotron maser radiation in inhomogeneous magnetic fields.

, ROBERT BINGHAM, Rutherford Appleton Laboratory, ALAN CAIRNS, IRENA VORGUL, Univ. of St-Andrews, BARRY KELLETT, Rutherford Appleton Laboratory, ALAN PHELPS, KEVIN RONALD, DAVID SPEIRS, SANDRA MCCONVILLE, ADRIAN CROSS, CRAIG ROBERTSON, CRAIG WHYTE, Univ. of Strathclyde — Cyclotron masers are important laboratory devices and play a major role in planetary and stellar radio emission. Recently we have shown that a cyclotron maser instability driven by a horseshoe shaped distribution in velocity space may be responsible for the observations. A long standing problem though is how the radiation generated at frequencies below the upper hybrid resonance, gets onto the higher frequency branch of the dispersion curve that connects to the vacuum propagation branch. Here we consider some of the dispersion properties of waves in the presence of energetic particle populations in the shape of a horseshoe and ring distribution in velocity space. The analysis is carried out in a homogeneous and an inhomogeneous magnetic field and demonstrates that the extraordinary mode that is initially driven unstable by the energetic particles can couple to the vacuum regime and escape the region.

10:42AM NO7.00007 Fiber-Based, Spatially and Temporally Shaped Picosecond UV Laser for Advanced RF Gun Applications[1]

, C. SIDERS, S. ANDERSON, S. BETTS, D. GIBSON, J. HERNANDEZ, M. JOHNSON, I. JOVANOVIC, D. MCNABB, M. MESSERLY, J. PRUET, M. SHVERDIN, A. TREMAINE, F. HARTEMANN, C.P.J. BARTY, LAWRENCE LIVERMORE NATIONAL LAB TEAM — The UV laser system has been specifically designed for advanced rf gun applications, with a special emphasis on the production of high-brightness electron beams for free-electron lasers and Compton scattering light sources. The laser pulse can be shaped to a flat-top in both space and time with a duration of 10 ps FWHM, rise and fall times under 1 ps, and pulse energy of 50 micro-joules at 261.75 nm. A fiber oscillator and amplifier system generates a chirped pump pulse at 1047 nm; stretching is achieved in a chirped fiber Bragg grating; recompression to 1 ps FWHM is achieved with a single multi-layer dielectric grating based compressor. A two stage harmonic converter frequency quadruples the beam. Temporal shaping is accomplished with a Michelson-based ultrafast pulse stacking device with nearly 100% throughput.

[1]This work was performed under auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7504-Eng-48.

10:54AM NO7.00008 Electromagnetic Simulation Studies of Photocathode Sources[1]

, MARK HESS, CHONG SHIK PARK, Indiana University Cyclotron Facility — We present the results of electromagnetic simulation studies on space-charge dominated electron beams produced by photocathode sources. In particular, we demonstrate the computational requirements on the Green's function based simulation code IRPSS (Indiana Rf Photocathode Source Simulator) for obtaining relative space-charge electromagnetic field errors of at most 1%, and show how these fields compare with electrostatic based field solver methods. We also present the results of a multislice method used within IRPSS for modeling electron bunches, which approximates a local region of beam density as a zero longitudinal thickness slice. We show how these results can be applied to realistic photocathode experiments, such as the 1.3 GHz AWA photoinjector experiment at Argonne National Laboratory [1].

[1] P. Schoessow, et al, The Argonne Wakefield Accelerator Overview and Status, Proceedings of PAC'03, Washington, D.C., p.2596.

[1]This research is supported by the NSF (PHY-0552389) and by the DOE (DE-FG0292ER40747).

11:06AM NO7.00009 Relativistic Electron Beam Tunneling Through an Overdense Plasma

, A.G. SGRO, Los Alamos National Laboratory — 3D simulations of an electron beam encountering an over dense background plasma show that at early times the beam is disrupted by the beam plasma instability. As the beam source continues to emit, background electrons from regions progressively further from the beam source are ejected radially leaving the background ions in the region of the beam. These ions neutralize the beam charge and allow the beam to regain its identity and continue to propagate through the plasma. Thus over long timescales the beam basically digs a channel through the over dense plasma through which it then propagates with approximately its initial average radius without any evident further instability. Previously, this effect has been shown in 2D simulations [1] which resolved only axisymmetric modes, and then in 3D with coarse spatial resolution [2]. These new finely resolved 3D simulations show that non axisymmetric modes grow to larger amplitudes than axisymmetric ones. The result, then, is that the beam acquires a significant non axisymmetric structure while, over long timescales, digging a channel through the background and propagating through it. (LAUR-07-4723)

[1] A. G. Sgro and T. J. T. Kwan, Phys. Plasmas 10, 849 (2003)
[2] A. G. Sgro, Bull. Am. Phys. Soc. 49 (11), 96 (2004).

11:18AM NO7.00010 Design considerations and parameter study for a 0.5TeV PWFA afterburner[1]

, CHENGKUN HUANG, W. LU, M. TZOUFRAS, M. ZHOU, V.K. DECYK, C. JOSHI, W.B. MORI, UCLA — A recent plasma wakefield acceleration (PWFA) experiment using short (~100fs), high peak current (>10KA) electron beam as driver has demonstrated sustained acceleration gradients of ~50GeV/m over 85 cm distance [1]. The rapid progress of PWFA experiments has attracted interest regarding the possibility of making an afterburner for a linear collider. In the afterburner concept, an electron beam is placed into the wakefield to extract energy deposited in the wake. We investigate the afterburner concept based on the present understanding of the key physics. Possible design scenarios such as single stage acceleration or integrated design with plasma lens final focusing are studied. The final energy, charges, emittance, energy spread and energy stability of the accelerated electron beam are taken as intrinsic design considerations. Parameters are suggested for a 0.5 TeV afterburner. We also present full scale 3D particle-in-cell simulations of the possible design using a highly efficient and accurate quasi-static code QuickPIC.

[1] Blumenfeld et. al., Nature 445, 741 (2007).

[1]Work supported by DOE and NSF.

11:30AM NO7.00011 Intense coherent THz radiation from two-color laser-gas interactions

, KI-YONG KIM, BALAKISHORE YELLAMPALLE, JAMES GLOWNIA, ANTOINETTE TAYLOR, GEORGE RODRIGUEZ, Los Alamos National Laboratory — Strong terahertz (THz) electromagnetic pulse generation is of current interest for applications in rapid THz imaging and nonlinear THz spectroscopy. While intense THz fields exceeding MV/cm can be obtained from large facility sources such as free electron lasers and synchrotron-based sources, there is a demand for high-power tabletop-scale THz sources. Recently, strong THz pulse generation was observed upon mixing the fundamental and its second harmonic laser fields in air. The underlying mechanism has been examined and understood in the context of a plasma current model, in which a directional transverse plasma current can be produced when the bound electrons of gas atoms are liberated via phase-sensitive tunneling ionization and accelerated in the asymmetric laser field, such as a mixed two-color field. This current surge can occur on the timescale of laser pulse duration (<50 fs), thus producing an electromagnetic pulse at THz frequencies in the far-field. We have investigated the THz generation mechanism using our 0.5 TW Ti:sapphire laser system. We have also observed intense THz radiation with peak field amplitude of 150 kV/cm with 2 THz bandwidth filtering, and energy of >4 microjoule per pulse with a spectral bandwidth in access of 70 THz.

11:42AM NO7.00012 Second Harmonic Generation in the Blowout Regime of Laser Wakefield Accelerators[1]

, DANIEL GORDON, Naval Research Laboratory, BAHMAN HAFIZI, Icarus Research, Inc., ANTONIO TING, Naval Research Laboratory, DMITRI KAGANOVICH, Icarus Research, Inc., PHIL SPRANGLE, Naval Research Laboratory — Analysis and simulations of the blowout regime of laser wakefield accelerators reveal that the density gradients associated with electron cavitation can lead to strong conical emission of radiation at the second harmonic of the laser frequency. The frequency spectrum and angular distribution of this radiation carries information about the structure of the cavitation region. This information might be useful as a diagnostic of the "plasma bubble" which is observed in simulations of quasi-monoenergetic acceleration in laser wakefields.

[1]Work supported by Department of Energy and Office of Naval Research

11:54AM NO7.00013 Coherent and incoherent radiation from ultra-intense laser interaction with nanostructured nickel nanowire ('velvet') targets[1]

, ROBIN MARJORIBANKS, MARINA SERVOL[2], PAUL FORRESTER, HART LEVY, LUKE MCKINNEY, BRETT TEEPLE, YVES CANDELA[3], University of Toronto, JEAN-CLAUDE KIEFFER, INRS-EMT, SIMON LE MOAL[4], GABOR KULCSAR, JOHN SIPE, University of Toronto, PATRICK AUDEBERT, JEAN-PAUL GEINDRE, LULI, CEA/CNRS/Ecole Polytechnique, ANNE HERON, JEAN-CLAUDE ADAM, CPhT, CEA/CNRS/Ecole Polytechnique — Nickel nanowires ('velvet') are a pure metallic anisotropic nanostructured material, averaging as much as one-quarter of solid density, that does not support material polarization- or current-densities required for Fresnel reflection. Since they present $> 90\%$ absorption and an effective skin-depth on the order of $1\mu m$ for intense laser light, they have been shown to be efficient x-ray converters. We show theoretical and experimental results of their behaviour under a range of irradiation conditions, from small-signal up to very clean pulses of relativistic-intensity laser light, including their transition from an effective dielectric to an effective metal, as the result of the generation of relativistic Brunel electrons.

[1]Supported by NSERC.
[2]& INRS-EMT
[3]& Institut d'Optique
[4]& Ecoles des Mines de Paris

12:06PM NO7.00014 Compton Scattering in Ignited Thermonuclear Plasmas[1]

, FREDERIC HARTEMANN, CRAIG SIDERS, CHRIS BARTY, LLNL — Inertially confined, ignited thermonuclear D-T plasmas will produce intense blackbody radiation at temperatures T $\sim$ 20 keV; it is shown that the injection of GeV electrons into the burning core can efficiently generate high-energy Compton scattering photons. Moreover, the spectrum scattered in a small solid angle can be remarkably monochromatic, due to kinematic pileup; peak brightness in excess of 10^{29} photons/(mm^2 x mrad^2 x s x 0.1% bandwidth) are predicted. Electron focusing of the γ-rays could produce electromagnetic fields exceeding the Schwinger critical field.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

12:18PM NO7.00015 Effect of radiation back-reaction on the interaction of super-strong laser fields with plasmas.

, IGOR V. SOKOLOV, Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI 48109, JOHN A. NEES, VICTOR P. YANOVSKY, Center for Ultrafast Optical Science and FOCUS Center, University of Michigan, Ann Arbor, MI 48109, NATALIA M. NAUMOVA, GERARD A. MOUROU, Laboratoire d Optique Appliquee, UMR 7639 ENSTA, Ecole Polytechnique, CNRS, 91761 Palaiseau, France — We analyze the effect of self-force on a single electron and on plasma electrons giving attention to the electromagnetic energy generated by non-linear Thomson scattering. The effect is essential if the scattered energy is comparable with the rest-mass energy of the electron in the frame of reference where the electron was initially at rest. We develop a method for solving the Lorentz-Abraham-Dirac equation and accounting for radiation in a self-consistent manner. The solution is then applied to the interactions of super-strong laser fields with an electron and a plasma layer including the presence of strong charge separation fields. This scheme allows a simulation of resulting radiation with spatial and spectral distributions, and demonstrates the possibility of efficient conversion (up to several %) of incident radiation to γ-ray emission at intensities of $\sim 10^{22}$W/cm^2, recently achieved in experiments.

9:30AM - 9:30AM –

Session NP8 Poster Session V: MHD and Waves; Inertial Confinement Fusion II and HEDP Diagnostics; C-Mod Tokamak; ITER and Magnetic Fusion Development Rosen Centre Hotel Grand Ballroom, 9:30am - 12:30pm

NP8.00001 MHD AND WAVES –

NP8.00002 2D Structure of RWM Plasma[1]

, DAVID HANNUM, G. FIKSEL, C.B. FOREST, R.D. KENDRICK, University of Wisconsin-Madison — The rotating wall machine is a linear screw-pinch built to study the role of different wall boundary conditions on the resistive wall mode (RWM). Its plasma is created by a hexagonal array of electrostatic guns. The central seven guns can be biased to discharge up to 1 kA of current. A probe inserted from the opposite end of the chamber combines magnetic pickup loops with singletip Langmuir electrodes. The loop signals are electronically integrated for a current measurement, while the singletip analysis employs a multivariable fitting routine on the I-V curve to derive the traditional Langmuir measurements. The probe can move over the length of the 1.2-meter long plasma column for 2D profiles of q, T_e, n_e and V_p in r and z. Individual gun streams are seen to coalesce into a single plasma column, with density peaking in the center even as the plasma edge spreads out to the wall.

[1]Supported by US DoE

NP8.00003 Identification of the resistive wall mode in the rotating wall machine

, W.F. BERGERSON, university of wisconsin, C.B. FOREST, G. FIKSEL, D. HANNUM, R. KENDRICK, S. OLIVIA, J.S. SARFF, ROTATING WALL MACHINE TEAM — The MHD stability properties of a line-tied plasma have been studied in a linear screw pinch device. Both an internal and external kink instability are observed to grow when the safety factor $q = \frac{4\pi^2 r^2 B_z}{\mu_0 I_p(r) L}$ approaches 1 inside the plasma. The growth rate of the internal kink is independent of the wall time, while the external kink growth scales with the wall time, as predicted by theory. After a brief growth phase, the modes saturate and create a helical equilibrium. Evidence of the internal modes suppressing the external kink will be presented. The main diagnostics for characterizing the MHD activity are a 2D array of 80 radial magnetic field pickup coils surrounding the plasma column, a segmented anode, which serves to measure current distribution inside the plasma, and an array of 40 poloidal and axial magnetic field coils just inside the conducting shell. These sensors identify a dominant poloidal mode m=1 and axial mode n=1 kink structure. This work was supported by the DoE.

NP8.00004 Engineering design and construction of a spinning conducting shell to stabilize the RWM in a cylindrical, line-tied screw pinch, ROCH KENDRICK, University of Wisconsin, Madison, CARY FOREST — The primary goal of the rotating wall machine is to demonstrate the stabilization of the resistive wall mode using rotating metal walls. This poster describes the design and construction of a spinning shell for the rotating wall machine. The plasma is a 1 meter long, 10 cm radius cylindrical plasma column that has recently shown the existence of a resistive wall mode for sufficiently large currents. The plasma is surrounded by two shells: one is a 0.5 mm thick, stationary shell at the plasma boundary (with a shell time of 7 ms); and the second is a 0.5 mm thick shell at 12 cm radius, mounted inside a carbon fiber spinning tube. The carbon fiber tube is in turn supported by foil bearings and driven by an air turbine, technologies which should easily allow the shell to spin at rotation frequencies up to 100 Hz. These frequencies should be adequate for demonstrating the stabilization of the MHD.

NP8.00005 The effect of finite parallel thermal conductivity on pressure-induced magnetic islands in three-dimensional equilibria[1], M. SCHLUTT, C.C. HEGNA, University of Wisconsin — A boundary layer analysis is used to investigate the formation of pressure-induced magnetic islands in three dimensional stellarator equilibria using a resistive MHD model. Previous analytic calculations have assumed effectively infinite heat conduction along the magnetic field lines. However, if the islands are sufficiently small in width, there is a competition between parallel and perpendicular transport processes due to the very long distance path along the magnetic field in the island region. The present calculation revisits the analytic island work using expressions for the pressure profile that account for the effect of finite parallel heat conductivity. The resulting analysis aims to provide a unifying theory for pressure-induced islands in three-dimensional equilibria encompassing both extreme limits of the parallel transport processes in the island region.

[1]Supported by U.S. DOE Grant No. DEFG0299ER54546.

NP8.00006 Experimental Study of Driven Magnetic Relaxation in a Laboratory Plasma, S. HSU, T. MADZIWA-NUSSINOV, D. SIRAJUDDIN, M. LIGHT, LANL — The physics goal of the Driven Relaxation Experiment (DRX) is to form and sustain simply-connected driven-relaxed plasmas above the first Jensen-Chu linear resonance of the force-free equation (where the first resonance is the "flipped" Rosenbluth-Bussac spheromak). As shown recently by Tang & Boozer (PRL, 2005), the linear resonances are regularized in partially relaxed systems, thus removing the energy barriers which have been thought to constrain relaxed states to exist only below the first resonance. DRX will apply an "over-driven" boundary condition at the coaxial gun source, with $\lambda_{\rm gun} \approx 30$ m$^{-1} \approx 3\lambda_1$. The DRX power system (10 kV, 125 kJ) will form and sustain the ~ 10 eV plasma for about 0.5 ms, which is about 10 Sweet-Parker reconnection times and sufficient for the plasma to reach a driven-relaxed steady-state. We will measure the 2D structure of the equilibrium magnetic field and compare it with the first several linear eigenmodes of the force-free equation, and subsequently study the k-spectrum of the magnetic energy as well as the dynamics of relaxation. Other topics we will study include magnetic flux amplification and the role of boundary elongation on equilibrium/stability. Better understanding of these issues could lead to new ideas for confinement configurations. This poster will provide an overview of DRX and first experimental data. Supported by the LANL LDRD Program.

NP8.00007 Physical Interpretations of Magnetohydrodynamic Invariants, MARTIN MICHALAK, BHIMSEN SHIVAMOGGI, University of Central Florida — Invariants arising from gauge transformations of magnetohydrodynamic equations are developed mathematically. Insights into physical interpretations of these invariants are considered.

NP8.00008 Beyond the Intelligent-Shell concept: the Clean-Mode-Control, PAOLO ZANCA, LIONELLO MARRELLI, GABRIELE MANDUCHI, GIUSEPPE MARCHIORI, Consorzio RFX Euratom-Enea Association, Corso Stati Uniti 4, 35127 Padova, Italy — Due to their discrete nature a grid of active coils for the feedback control produces an infinite sequence of sideband harmonics in the magnetic field. If the sensors have the same periodicity as the coils, as in the Intelligent Shell scheme, the aliasing of the sidebands determines a systematic error on the Fourier analysis of the measurements. This is a drawback for the control of those perturbations that cannot be suppressed by the feedback, but only reduced in their saturation level, as the non-linear tearing modes of reversed field pinches. We have derived analytical formulas for the subtraction of the sidebands, implemented in a real-time correction algorithm of the Fourier analysis. The Fourier harmonics so obtained are used as feedback variable of a new control scheme named Clean-Mode-Control (CMC). The first tests of CMC in RFX-mod have given interesting results in the tearing modes control: besides a reduction of the edge radial field and the plasma surface distortion, systematic rotations with frequencies up to 100Hz are seen. These phenomena will be interpreted using a MHD model of the CMC.

NP8.00009 Advances in Thermodynamic Mixed Materials Modeling for Resistive MHD, JOHN LUGINSLAND, MICHAEL FRESE, SHERRY FRESE, NumerEx — There is continued interest in the modeling of mixed materials for a variety of high current plasma applications ranging from advanced current interrupters via high voltage fuses to high energy density applications, such as high-dose x-ray production via intense electron emission and inertial fusion energy via z-pinch technology. The challenge with mixed materials is the constituent components may be very small physically, requiring high spatial resolution to capture the individual materials. NumerEx has developed a means to build mixed material models from the constituent equations of state, allowing drastically reduced resolution while still retaining the sufficient fidelity for the thermodynamic behavior. We show the protocol for starting with "microscopic" simulations where the individual materials are resolved, and using these calculations to build a "macroscopic" EOS and resistivity tables of a mixed, homogenized material. We demonstrate a new V&V technique for comparing thermodynamic properties between experimental results and mixed materials simulations.

NP8.00010 Pulsed Alfvén Wave Experiments in a Helicon Plasma Source, ALEX HANSEN, SAEID HOUSHMANDYAR, EARL SCIME, West Virginia University Physics Department — Experiments to test a model for ion heating in the fast solar wind based on ion cyclotron damping of MHD turbulence driven by nonlinearly interacting, low frequency Alfvén waves [Matthaeus et. al., 1999], are being conducted in the West Virginia University HELIX (Hot hELIcon eXperiment) device in argon and helium plasmas. It is argued that counter-propagating waves arise from reflection of the waves off of a gradient in the Alfvén speed. The HELIX device has a similar speed gradient profile to that found in the solar corona: a short region of high Alfvén speed followed by an expansion region of lower Alfvén speed. Here we present measurements of pulsed Alfvén waves that have been launched via amplitude modulation of the steady-state RF drive of the plasma-creating (m = 1) helicon antenna. Measurements of wave magnetic field structure, wave phase speed, and the radial profile of the wave amplitude will be presented as a function of plasma density and magnetic field strength in the helicon source.

NP8.00011 Alfvén wave Measurements in HelCat at UNM, RALPH KELLY, CHRISTOPHER WATTS, YUE ZHANG, MARK GILMORE, University of New Mexico — Neutral damping of Alfvén waves has been theorized to be partially responsible for the heating of the sun's corona. As such, more research is needed to better understand the relationship between Alfvén waves and ion and neutral density. This paper describes one method to launch and observe Alfvén waves in a high-density Argon plasma. The Alfvén waves are launched with a commercial inductor (emitter) and detected with a hand wound B-dot coil. Construction of the emitter, detector and amplifier circuit is described. The Argon plasma is created using the helicon source on HelCat, a linear plasma device at the University of New Mexico. HelCat is a 4 meter long, 50 cm diameter machine with a helicon source on one end and hot cathode source on the other. Initial data collected indicating the presence of Alfvén waves in Argon plasma is presented. Neutral density will be adjusted by pre-ionizing the gas with the cathode and/or an external UV lamp.

NP8.00012 Linear Theory of n=0 Geodesic Acoustic Mode

H.V. WONG, H. BERK, T. ZHOU, IFS, Univ. of Texas at Austin — The n=0 geodesic acoustic mode (GAM) has been observed in JET and D- III D experiments, and it is frequently accompanied with pronounced fast frequency chirping. A numerical investigation with the CASTOR code reveals that a global GAM mode arises if the continuum geodesic frequency has a local maximum as a function of radius. The global GAM properties are characterized by: a very small upward frequency shift from the continuum, a radially localized electrostatic component with poloidal numbers m=0,1 and with magnetic coupling to a nonlocalized m=2 component. Here we develop an analytic MHD theory of this n=0 global GAM in a toroidal plasma with r/R taken as order the square root of beta, with beta small. In the analysis we choose to start from the MHD quadratic form (with inertial terms) , we take the mode to primarily have a density perturbation and we find that the magnetic perturbation in the localization region of the mode to be one order of beta smaller than the density perturbation, though this component extends throughout the plasma. Indeed we verify that the existence of a linear global mode requires that the continuum GAM profile have a maximum as a function of radius. The theory shows that the frequency of the global GAM eigenmode is shifted from the maximum continuum GAM frequency, Ω_{Gm} by $\delta\omega = a(\beta r_{Gm})^2\partial^2\Omega_{Gm}/\,\partial r^2$, where we developed an asymptotic matching scheme to determine the constant a. We found precise agreement of the asymptotic method with the numerical results for a specific q-profile in the high aspect ratio, low beta plasma.

NP8.00013 Radial structures and nonlinear excitation of Geodesic Acoustic Modes[1]

LIU CHEN, Department of Physics and Astronomy, University of California, Irvine, FULVIO ZONCA, Associazione EURATOM-ENEA sulla Fusione — In this paper, we show that GAMs constitute a continuous spectrum due to radial inhomogeneities. The existence of singular layer, thus, suggests linear mode conversion to short-wavelength kinetic GAM (KGAM) via finite ion Larmor radii. This result is demonstrated by derivations of the GAM mode structure and dispersion relation in the singular layer. At the lowest order in $k_r\rho_i$, with k_r the radial wave vector and ρ_i the ion Larmor radius, the well known kinetic dispersion relation of GAM is recovered. At the next relevant order, $\mathrm{O}(k_r^2\rho_i^2)$, we show that KGAM propagates in the low-temperature and/or high safety-factor domain; i.e., typically, radially outward, and a corresponding damping rate is derived. In this work, we also show that, while KGAM is linearly stable due to ion Landau damping, it can be nonlinearly excited by finite-amplitude DW turbulence via 3-wave parametric interactions. The resultant 3-wave system exhibits the typical prey-predator self-regulatory dynamics.

[1]Work supported by U.S. DOE Contract DE-AC02-CHO-3073 and NSF Grant ATM-0335279.

NP8.00014 Spectral Gap of Shear Alfvén Waves in a Periodic Array of Magnetic Mirrors[1]

ROGER MCWILLIAMS, YANG ZHANG, WILLIAM HEIDBRINK, HEINZ BOEHMER, UC Irvine, GUANGYE CHEN, BORIS BREIZMAN, UT Austin, STEPHEN VINCENA, TROY CARTER, DAVID LENEMAN, WALTER GEKELMAN, BRIAN BRUGMAN, UCLA, UC IRVINE TEAM, UT AUSTIN COLLABORATION, UCLA COLLABORATION — A multiple magnetic mirror array is formed at the LArge Plasma Device (LAPD), to study axial periodicity-influenced Alfvén spectra. Shear Alfvén Waves (SAW) are launched by antennas inserted in the LAPD plasma. From radial wave field scans with B-dot probes at many axial locations, SAW standing-wave formation and wave refraction in mirror cell(s) are observed. Alfvén wave spectral gaps and continua are formed similar to wave propagation in other periodic media due to the Bragg effect. The width of the propagation gap scales with the modulation amplitude according to the solutions of Mathieu's equation. A 2-D finite-difference code modeling SAW in a mirror array configuration shows similar spectral features. Machine end-reflection conditions and damping mechanisms including electron-ion Coulomb collision and electron Landau damping are important for simulation.

[1]Work supported by DOE DE-FG02-03ER54720

NP8.00015 Tearing mode transitions induced by electrostatic turbulence

FULVIO MILITELLO, IFS, University of Texas and CMPD, FRANCOIS WAELBROECK, RICHARD FITZPATRICK, WENDELL HORTON, IFS, University of Texas — The effect of electrostatic turbulence on the stability and propagation of the magnetic islands is investigated numerically. The physical model used is a 2-D version of the Hasegawa-Wakatani equations, which is the simplest model of electrostatic turbulence that takes into account the effect of magnetic shear and finite resistivity. Our equations are extended to include a curvature term, that makes the model linearly unstable to interchange instability. The problem is solved numerically in a slab box by using a finite difference, fully implicit code that uses PETSc libraries. Turbulence is found to cause transitions between the different roots for the propagation velocity of the mode. The transitions take the mode towards roots with slower propagation that are characterized by locally flattened profiles. At constant velocity, the effect of the turbulence is to increase the drive for the tearing mode but this effect may be compensated by the generally stabilizing effect of reducing the propagation velocity.

NP8.00016 A feasibility study for the existence of precursor phenomena in magnetohydrodynamic waves

HOGUN JHANG, National Fusion Research Center — The existence of precursor or forerunner waves, which propagate faster than the main signal, is a feature of linear wave propagation in a dispersive medium. Precursors were first predicted by Sommerfeld and Brillouin, and have been observed in the electromagnetic and the fluid surface wave propagation, in which non-monotonic dispersion relations prevail. In the present work, a feasibility study is carried out whether such a precursor wave exists in magnetized plasmas in the excitation and propagation of Alfven waves. The condition for the existence of the precursors is deduced from the dispersion relations of Alfven waves, and the characteristics of the precursors are investigated. Possible application of the present study to astrophysical and laboratory fusion plasmas are also discussed. Finally, an experimental setup is proposed for the observation of the Alfven precursor waves.

NP8.00017 Nonlinear coupling between drift waves and streamers in LMD-U[1]

T. YAMADA, S.-I. ITOH, T. MARUTA, Y. NAGASHIMA, S. SHINOHARA, K. TERASAKA, M. YAGI, S. INAGAKI, Y. KAWAI, Kyushu Univ., N. KASUYA, A. FUJISAWA, K. ITOH, NIFS — Recent theories and simulations on drift wave turbulence revealed that the coupling between drift waves should generate streamers. A streamer is radially elongated and poloidally localized structure, therefore, it is expected to enhance the cross-field transport and have large effects on the plasma confinement. However, few streamers have been identified in toroidal and linear plasmas. We applied a 64-channel poloidal probe array to the LMD-U linear plasma in order to investigate poloidal structure of drift wave turbulence, and identify the occurrence of streamer events successfully. Furthermore, two-dimensional (poloidal wave number and frequency) spectra showed broadband fluctuations superposed with a couple of parent modes which satisfy the linear dispersion relation, and many quasi-modes which do not satisfy the dispersion relation. It should be highlighted that the first application of two-dimensional bi-spectral analysis revealed the cascading process from parent drift waves to quasi-modes and broadband components, and the process of a streamer generation.

[1]This work was partly supported by the Grant-in-Aid for Specially-Promoted Research (16002005) of MEXT, Japan.

NP8.00018 Magnetic field effects on velocity shear-driven ion cyclotron instabilities[1] , E. TEJERO, A. EADON, E. THOMAS, Auburn University, W.E. AMATUCCI, Naval Research Laboratory — Flows generated in plasmas due to the presence of mutually perpendicular electric and magnetic fields are of relevance to both the fusion and space plasma communities. In particular, inhomogeneity in the flow can have both stabilizing and destabilizing effects on the plasma depending on the magnitude and scale length of the inhomogeneity. Studies in the ALEXIS device, a 170-cm long, 10.2-cm diameter magnetized plasma column, seek to determine the stability regimes for driven inhomogeneous flows. This poster focuses on the effect of the axial magnetic field strength on the behavior of ion cyclotron waves observed in ALEXIS plasmas containing radially localized dc electric fields. This presentation discusses the clear correlation observed between sheared azimuthal E x B plasma flows and the spatial localization of ion cyclotron instabilities observed in ALEXIS. Further, it is shown that the effect on the oscillations due to varying the magnetic field is consistent with a Doppler-shifted frequency resonating with a harmonic of the ion cyclotron frequency.

[1]Supported by US DOE Grant DE-FG02-00ER54476.

NP8.00019 Study of the low-frequency ion-cyclotron turbulence in a cylindrical plasma magnetically confined , STEVE JAEGER, ABDELILAH AJENDOUZ, CEDRIC BRAULT, Univ. de Provence, AMINE ERRADI, Univ. de Versailles, THIERY PIERRE, CNRS, ALEXANDRE ESCARGUEL, CYRIL REBONT, NICOLAS CLAIRE, Univ. de Provence, ERIC FAUDOT, STEPHANE HEURAUX, Univ. de Nancy, KAMAL QUOTB, CNRS, PIIM, LABORATOIRE DE PHYSIQUE DES INTERACTION IONIQUES ET MOLECULAIRES, CNRS-UNIV. DE PROVENCE - XPM TEAM, LPMIA, LABORATOIRE DE PHYSIQUE DES MILIEUX IONISES, CNRS-UNIV. H.POINCARE COLLABORATION — A cylindrical column of magnetized plasma is produced by means of the hot cathode laboratory device MISTRAL using various gases (Neon, Argon, Krypton). In usual experimental conditions, strongly nonlinear low frequency instabilities in the ion cyclotron range are recorded. A transition towards ion cyclotron turbulence appears to be triggered by a threshold value of the radial electric field. In order to investigate the characteristics of the instabilities and the phenomena responsible for the destabilization of the plasma column, detailed measurements are performed using various diagnostics (probe arrays, ultra-fast and intensified cameras, Laser Induced Fluorescence, spectroscopy, microwave resonance). The results are compared with both a theoretical model of the ion cyclotron instability and Particle in Cell simulation of the instability.

NP8.00020 Focusing light with subwavelength aperture due to surface plasma , K.R. CHEN, Physics Dept. and Plasma and Space Science Center, National Cheng Kung University, Taiwan — Diffraction limits any optical system; in fact, it affects all wave fields. As a reminiscent of Heisenberg uncertainly principle for quantum mechanics, diffraction limit restricts the minimum value of the product of divergent angle and width of light beam and sets the achievable smallest spot size of a focused light at the order of wavelength. We study an innovative approach and the physical mechanism using surface plasma to focus propagating light to a width below the scale of wavelength and are investigating the possibility to break the diffraction limit and its implications in fundamental physics. This process is simulated with finite-difference time domain (FDTD) method; the dispersive material such as silver film is modeled by auxiliary difference equation (ADE) method with Drude poles and thus the phasor polarization current is calculated. Such a focused light may be useful to imaging, sensing, lithograph, optical storage, photonic circuit, and many other applications.

NP8.00021 Energy transfer via Weibel and two-stream instabilities in two-temperature electron-ion plasmas , JAEHONG PARK, ERIC BLACKMAN, XIANGLONG KONG, CHUANG REN, University of Rochester — Whether an efficient collisonless temperature equilibration mechanism exists for a two-temperature ion-electron plasma, with $T_i > T_e$, is important for understanding astrophysical phenomena such as radiatively inefficient accretion flows and relativistic collisionless shocks in Gamma-ray bursts. Here we study whether the two-stream and Weibel instabilities driven by proton counter-streaming and/or temperature anisotropy can be such a mechanism. Analysis and PIC simulations show that the Weibel instability induces only a weak electro-ion coupling in either non-magnetized [Ren, Blackman, and Fong, Phys. Plasmas, 14:012901 (2007)] or magnetized plasmas. The two-stream instability is found to be more effective than the Weibel instability for the electron-ion coupling. This work is supported by the U.S. Department of Energy under Grant Nos. DE-FC02-04ER54789 and DE-FG02-06ER54879.

NP8.00022 Dynamic manipulation of electromagnetic waves in magnetized plasmas: deceleration, compression and acceleration , YOAV AVITZOUR, The University of Texas at Austin, GENNADY SHVETS, Department of Physics, The University of Texas at Austin — We study the properties of electromagnetic fields propagating in magnetized plasmas with emphasis on propagation modes with very low group velocities. The dramatic slowdown of a wave entering such a plasma results in compression of the wave energy. In plasma, unlike in other media that demonstrate low group velocity, the compressed energy is stored in the longitudinal component of the EM field and is not transferred to the medium. The compressed wave can then be used for electron acceleration in the plasma. We also demonstrate temporal compression of the transmitted wave by rotating the magnetic field or increasing its amplitude while the wave is in the plasma. Depending on the plasma frequency, the transmitted signal can be upshifted or unchanged in frequency. We present analytical and numerical results for the problem in one, two and three dimensions.

NP8.00023 Properties of Whistler Spheromaks[1] , REINER STENZEL, J. MANUEL URRUTIA, KYLE STROHMAIER, UCLA — A loop antenna inserted into a large magnetized laboratory plasma is used to induce a field-reversed configuration (FRC) in a large laboratory plasma. Upon reversal of the oscillating antenna current the FRC splits into two emerging spheromaks. The magnetic structures develop helicity of opposite signs, propagates in the whistler mode along the ambient field away from the antenna. The propagation speed of these "whistler spheromaks" or 3D vortices decreases with increasing amplitude. When two counter-propagating spheromaks collide they merge into a stationary FRC whose axis frequently precesses in the direction of the toroidal electron drift. Whistler spheromaks and FRCs are subject to a non-collisional (inertial or stochastic) damping mechanism: Electrons are accelerated along a neutral line by a parallel electric field. Magnetic energy is converted into electron kinetic energy within one cycle. The electron distribution is non-Maxwellian and likely anisotropic since the energized electrons give rise to an instability of whistler modes at different frequencies.

[1]Work supported by DOE/NSF and AFOSR.

NP8.00024 Whistler instabilities in EMHD spheromaks and FRCs[1] , J. MANUEL URRUTIA, KYLE STROHMAIER, REINER STENZEL, UCLA — In a large laboratory plasma anisotropic electron distributions are produced by accelerating electrons in magnetic null regions. These null regions are predominantly the toroidal null lines of field-reversed configuration (FRC) and spheromaks in the parameter regime of electron MHD (EMHD). The electrons gain energy from an inductive electric field along the separator thereby converting magnetic energy into electron kinetic energy. The non-adiabatic electron motion near null points produces non-equilibrium distributions which give rise to kinetic instabilities. The emission of whistlers from toroidal electron current rings is observed. Frequency spectra, amplitudes and wave magnetic field distributions are measured. Of particular interest is the source region which is not a toroidal rf current but two opposing poloidal current layers. Since the source region is of order of the whistler wavelength the instability appears to be absolute rather than convective. Possible instability mechanisms will be discussed.

[1]Work supported by DOE/NSF and AFOSR.

NP8.00025 Experiments on triggered whistler emissions[1] , KYLE STROHMAIER, J. MANUEL URRUTIA, REINER STENZEL, UCLA — Emission of whistler modes from a laboratory plasma with locally anisotropic electrons has been observed. In order to measure the spatial growth rate of the possibly convective whistler instability test whistler waves have been injected into the source region. The frequency is chosen near the most unstable mode (< 7 MHz $\simeq 0.3\omega_{ce}$). It is observed that the test wave is not amplified but the whistler emission is greatly enhanced. The emission can be distinguished from the test wave by its different field topology and frequency which chirps downward in time. Thus, the test wave triggers an enhanced emission of an absolute whistler instability. These findings will be compared with observations of triggered emissions in the magnetosphere.

[1]Work supported by DOE/NSF and AFOSR.

NP8.00026 Large-amplitude electron oscillations with spatially inhomogeneous ion densities? , BARBARA ABRAHAM-SHRAUNER, Washington University — No analytic solutions for large-amplitude electron oscillations in a cold plasma with immobile ions have been found for spatially inhomogeneous ion densities. The one-dimensional (spatial) electrons obey two fluid equations and two Maxwell equations for the electric field. The Eulerian variables are transformed to Lagrangian variables. The problem is then reduced to the equation of motion of an equivalent particle in one dimension and the Lagrangian time (orbital) given as an integral over the position. The expressions for the electron oscillations with immobile and spatially homogeneous ion densities are recovered. Several possible spatially inhomogeneous ion densities are explicitly solved but the electron density vanishes, an unphysical result. A particular generic solution for the electron position as a function of the Lagrangian position and time is shown by Lie symmetry methods to require spatially homogeneous ion densities. More general forms of spatially varying ion densities give a simple condition for a nonzero electron density. However, for the Jacobian elliptic functions secular terms that destroy the oscillation occur if either the modulus of the elliptic function or a coefficient of the Lagranian time depends on the Lagrangian position. The key restriction is Gauss' law. These results restrict perturbation solutions.

NP8.00027 Modified Budden problem associated with an energetic-particle population , A.N. KAUFMAN, LBNL & UCB, A.J. BRIZARD, SMC, E.R. TRACY, W & M — Our main motivation is to investigate what new effects are introduced in standard heating and/or current-drive scenarios when a non-Maxwellian population of energetic particles (e.g., fusion alphas) is taken into account. In particular, we investigate how energy from a wave supported by a population of energetic particles (e.g., Bernstein wave) can be transferred to a bulk-ion wave through the intermediary of a magnetosonic wave. For this purpose, a three-wave Budden model with two resonance layers is constructed that allows recirculation of energy fluxes around a rectangle in ray phase space. The transmission, reflection, and conversion coefficients for this extended Budden problem are calculated by ray phase- space methods and the modular-eikonal approach [1,2]. The analytical and numerical results show that all of the connection coefficients exhibit interference effects that depend on an interference phase that can be calculated from the coupling constants at each conversion point and the area enclosed by the rectangle. When one of the three waves is a negative-energy wave supported by an inverted energetic-particle population, the magnitude of the conversion coefficients can exceed 100%. Such amplification effects may provide a new form of alpha- channeling.

[1] Y. M. Liang, *et al.*, Phys. Lett. A **193**, 82 (1994).
[2] A. J. Brizard, *et al.*, Phys. Plasmas **5**, 45 (1998).

NP8.00028 A new normal form for multidimensional mode conversion[1] , E. TRACY, A. RICHARDSON, N. ZOBIN, William and Mary, A. KAUFMAN, UC Berkeley and LBNL — Linear conversion occurs when two wave types are locally resonant in a nonuniform plasma [1]. In recent work, we have shown how to incorporate a ray-based approach to mode conversion in numerical algorithms [2,3] for the most common type of conversion. Here, we present a new formulation that can deal with more general cases [4]. We exploit a new normal form for the 2X2 dispersion matrix defined such that the diagonals Poisson- commute with the off-diagonals (at leading order). Therefore, if we use the diagonals as ray Hamiltonians, the off- diagonals will be constant. Thus, the 2X2 dispersion matrix in normal form has a very natural physical interpretation: the diagonals are the uncoupled ray Hamiltonians and the off-diagonals are the coupling. We further discuss how to incorporate the normal form into ray tracing algorithms. 1] E. Tracy, A. Kaufman and A. Brizard, Phys. Plasmas **10** (2003) 2147. 2] A. Jaun, E. Tracy and A. Kaufman, Plasma Phys. Control. Fusion **49** (2006) 43. 3] E. Tracy, A. Kaufman and A. Jaun, to appear in Phys. Plasmas. 4] A. Kaufman, E. Tracy and A. Brizard, Phys. Plasmas **12** (2005) 022101. 5] E. Tracy and A. Kaufman, PRL **91** (2003) 130402.

[1]Supported by the NSF-DOE Program in Basic Plasma Physics and the DOE OFES.

NP8.00029 Quadratic Effects in Conversion[1] , ANDREW RICHARDSON, EUGENE TRACY, William and Mary, ALLAN KAUFMAN, UC Berkeley and LBNL — Phase space ray-tracing techniques can be used to solve wave problems exhibiting mode conversion [1,2]. The (x,k)-dependence of the dispersion matrix, $\mathbf{D}$, is linearized near the conversion, and the matrix is then converted back to an operator. The resulting coupled equations can be solved for the local fields. Matching these local solutions onto uncoupled WKB far-field solutions gives scattering coefficients which can be used to treat the mode conversion as a ray-splitting process. In this work, we study the effects of quadratic terms in $\mathbf{D}$ near a mode conversion. We show that for one spatial dimension, $\mathbf{D}$ can be put into normal form, where the diagonals contain quadratic corrections, and the off-diagonals are the constant coupling. The quadratic terms introduce phase corrections to the far-field coupled WKB solutions, while the local solutions have both amplitude and phase corrections. These corrections allow for better matching at the conversion, which we illustrate by comparing the asymptotic solution with a numerical solution for the 1-D conversion. 1] A. Jaun, E. Tracy and A. Kaufman, Plasma Phys. Control. Fusion 49, 43-67 (2007). 2] E. Tracy, A. Kaufman and A. Jaun, to appear, Phys. Plasmas (2007).

[1]Supported by the NSF-DOE Program in Basic Plasma Physics and the DOE OFES.

NP8.00030 Path Integrals and Mode Conversion[1] , N. ZOBIN, Mathematics Dept, William and Mary, A.S. RICHARDSON, E.R. TRACY, Physics Dept, William and Mary — The phase space path integral arises naturally in the ray-tracing approach to the solution of wave equations, including those which exhibit mode conversion. The wave evolution operator is related to the exponential of the dispersion matrix, and the path integral can be used to find this exponential using the method of operator symbols. Thus, the path integral can be used even in nonstandard conversions which are not of the "avoided crossing" type, and we hope to exploit this to develop new types of ray-based treatments for these conversions. In order to do this, a deeper understanding of the nature of this path integral will be useful. Here we show that the phase space path integral can be interpreted as a Fourier transform on the space of measures using a new formalism for infinite dimensional Fourier transforms proposed by Zobin. Approximate expressions for this type of Fourier transform are developed using entropy arguments and, in the classical limit where smooth ray trajectories exist, we recover the familiar sum over all histories. We also give an example for the case of a discrete phase space, in which smooth paths are not defined, but where the Fourier transform over measures can still be evaluated using entropic techniques.

[1]Supported by the NSF-DOE Program in Basic Plasma Physics.

NP8.00031 Direct comparison of full-wave and ray-tracing methods for a simple model of multi-dimensional mode conversion[1] , Y. XIAO, A. RICHARDSON, E. TRACY, William & Mary — Mode conversion can occur in a nonuniform plasma when two waves of different character are locally resonant. Jaun et al. have recently developed a numerical ray-tracing algorithm for realistic tokamak models that accounts for the ray splitting that occurs at conversions [1,2]. Here we present a comparison of ray-based and full-wave methods by considering a simple model consisting of a pair of coupled wave equations in two spatial dimensions. The two spatially-dependent wave speeds, $c_1(x,y)$ and $c_2(x,y)$ are distinct for almost all (x,y), and are equal only along a line where conversion occurs. We launch a WKB-type wave packet in channel 1. There is initially no excitation in channel 2. Absorbing boundary conditions are used to avoid reflections which would complicate the results. From the full-wave output, we compute the initial energy density as a function of position and consider its evolution along a family of rays which undergo conversion. These full-wave results are then compared to the ray-based predictions. [1] A.Jaun, E.Tracy and A.Kaufman, Plasma Phys. Control. Fusion **49**, 43-67 (2007). [2] E.Tracy, A.Kaufman and A.Jaun, to appear in Phys. Plasmas.

[1]Supported by the NSF-DOE Program in Basic Plasma Physics and the DOE OFES.

NP8.00032 Laboratory investigation of whistler and lower hybrid wave characteristics[1] , WILLIAM AMATUCCI, DAVID BLACKWELL, GURUDAS GANGULI, GEORGE GATLING, Naval Research Laboratory, DAVID WALKER, CHRIS COMPTON, SFA, Inc. — An experimental investigation of the generation and propagation of whistler and lower hybrid waves is underway in the NRL Space Physics Simulation Chamber. Wave propagation is being investigated in conditions simulating the Earth's radiation belt environment. These studies are carried out in both homogeneous plasma and plasma containing density structures. In homogeneous plasma, resonance cone propagation of the waves is observed, consistent with theoretical predictions. In plasma containing a density depletion layer, wave ducting within the layer has been observed. For these experiments, we have fabricated and tested transmitting and receiving magnetic loop antennas and electric field dipole receiving antennas. Preliminary comparisons of the two antenna styles indicate that loop antennas couple significantly more wave power into the plasma. Efforts are currently underway to further quantify these observations. Experimental results related to the propagation characteristics of whistler/lower hybrid waves under these conditions will be presented.

[1]Work supported by the Office of Naval Research.

NP8.00033 Superposition of Parallel and Perpendicular Flow Velocity Shears in Magnetized Hybrid-Ion Plasmas , TOSHIRO KANEKO, SHUICHI TAMURA, RYUTA ICHIKI, RIKIZO HATAKEYAMA, Department of Electronic Engineering, Tohoku University — Low-frequency instabilities modified by ion flow velocity shears are investigated using concentrically three-segmented ion and electron emitters in a modified double-ended Q-machine. When each of the emitters is individually biased, the perpendicular and parallel ion flow shears can be generated and superimposed on each other. The fluctuation amplitude of the drift wave which has an azimuthal mode number m=3 increases with increasing the parallel shear strength. When the perpendicular shear is superimposed on the parallel shear, the drift wave of m=3 changes into that of m=2 through a broadband turbulence state. Furthermore, the parallel shear strength required for the excitation of the drift wave becomes large with a decrease in the azimuthal mode number. On the other hand, the effects of a negative ion as one of the hybrid ions on the drift wave in the presence of the positive-ion flow shear are also investigated. The negative ion stabilizes the shear-modified drift wave, which is the opposite result to a number of earlier studies on the negative ion plasmas.

NP8.00034 Microwave heating of over-dense plasmas in the TJ-K stellarator , ALF KÖHN, GREGOR BIRKENMEIER, HENDRIK HÖHNLE, EBERHARD HOLZHAUER, WALTER KASPAREK, MIRKO RAMISCH, ULRICH STROTH, Institut fuer Plasmaforschung, Universitaet Stuttgart — In the stellarator TJ-K, over-dense plasmas are generated by means of microwaves at 2.45 GHz and 8.25 GHz. The plasma is characterized by densities $\leq 10^{18}$ m^{-3} and electron temperatures $\leq$ 20 eV. At the given plasma parameters, absorption of the O or X-waves at the fundamental cyclotron resonance is only possible through the Bernstein wave, which can be generated due to an O-X-B or X-B mode conversion process. Furthermore, absorption is possible at the upper-hybrid resonance or, if a R-wave is generated after multiple reflections between cut-off layer and wall, at the cyclotron resonance. In order to sort out the importance of the different heating mechanisms, experimental studies have been carried out in a wide parameter range. Power-modulation experiments with Langmuir-probe arrays and wave-field measurements are used to detect the local power-deposition profile. Dominant absorption is found at the upper-hybrid resonance. In order to optimise the O-X-B mode-conversion efficiency, a novel array antenna has been developed. Thus the angle between the microwave beam and the flux surfaces can be modified by tuning the microwave frequency. First experiments with this antenna will be presented. The experimental results are compared with simulations from a full-wave code.

NP8.00035 INERTIAL CONFINEMENT FUSION II AND HEDP DIAGNOSTICS —

NP8.00036 A Simple Model for ICF Double Shell Target Performance[1] , MORDECAI ROSEN, Lawrence Livermore National Laboratory — Hohlraum-driven double-shell capsules are being considered as ignition / moderate gain systems for the National Ignition Facility. We present a simple model for the performance of these double shell capsules by focusing on the dynamics of the inner Au shell and the DT gas within. We calculate the post shock conditions of the DT, followed by its adiabatic compression. At stagnation time, the ultra-high density Au shell is treated simply as a Fermi-degenerate system. We equate the peak kinetic energy of that shell to the internal energies of the DT and the Au upon stagnation. We close the system of equations via a pressure balance between the Au and the DT. This "hydro phase" of the analytic calculation results in predictions for peak DT density and temperature. We then calculate ignition criteria for this system and add a simple model for fusion burn-up and gain. Results from all of this are compared with published results of the simulations of Amendt et. al. (PoP 14, 056312 [2007]). We use our analytic formulae to study parameter variations such as DT initial density and radius as they vary with ICF driver scale.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

NP8.00037 2D LMJ target design for early ignition experiments , STEPHANE LAFFITE, STEPHANE LIBERATORE, PASCAL LOISEAU, CEA/DIF BP12 91680 Bruyeres le Chatel France — Achieving ignition is one of the objective of the "Laser MegaJoule" (LMJ), which will deliver up to 1.8 MJ and 600 TW. Several indirect drive target were designed to reach ignition on this facility. The nominal point design target, called A1040, is composed of a doped plastic capsule in a gold cylindrical hohlraum. Other experiments are planned before the laser being totally built. They include the attempt of ignition and burn of an ICF capsule with 40 laser quads (of 4 beams each), delivering up to 1.2 MJ and 390 TW. We present here the 2D design of two target requiring 1 MJ, 300 TW and 1.2 MJ, 360 TW of laser energy and power. For both targets, the hohlraum is cylindrical, made up with gold. Yield is about 10 for the smaller one, more than 15 for the other one. The beam passage through the laser entrance holes, the radiation symmetry and the susceptibility to laser-plasma interactions are analyzed.

NP8.00038 3D simulations of thermally induced expansion of beryllium microstructure in gas–filled NIF ignition targets[1] , M.M. MARINAK, N.R. BARTON, R. BECKER, S.W. HAAN, J.D. SALMONSON, Lawrence Livermore National Laboratory — X-ray preheat in the baseline gas-filled NIF ignition target is calculated to heat solid portions of the beryllium ablator hundreds of degrees Kelvin. Anisotropy in the resulting thermal expansion, due to crystal properties, causes the interfaces between the beryllium and cryogenic fuel, as well as the internal beryllium interfaces, to distort before the grains are melted by passage of the first shock. We quantify these effects for the full duration of the implosion. A 3D polycrystalline model is employed in ALE3D, a multiphysics arbitrary Lagrange Eulerian code, to calculate this expansion and the response to the first shock. It models the anisotropic elastic and plastic response, resolving individual grains. Perturbations in the fields and interfaces are then linked to a 3D HYDRA simulation of the remainder of the implosion. High-resolution simulations resolve modes up to $\ell \approx 2000$. These perturbations add to those originating from the native roughness on the embedded interfaces. We compare the magnitudes and spectral content of the different perturbation seeds.

[1]This work performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

NP8.00039 Strength and surface roughness of Be under laser irradiation , S.N. LUO, E.N. LOOMIS, S.R. GREENFIELD, D.L. PAISLEY, D. SWIFT, T. TIERNEY, R. JOHNSON, N. HOFFMAN, Los Alamos National Lab, H. LORENZANA, Lawrence Livermore National Lab — To examine the microstructure effect on dynamic strength and surface roughness of Be under laser irradiation, we have conducted dynamic loading experiments at the Trident laser facility on rolled foil, single crystal disk, equal channel angular extruded (ECAE) foil with 0.9% atom Cu doping, and sputtered Be with 0.9% atom Cu doping. Direct and confined laser ablation have been applied to Be samples at 532 nm and 1064 nm for 1D strain loading. The drive pulse, ranging from 2 ns to 2000 ns in duration, is shaped temporally as square, Gaussian, half Gaussian (ramping and Taylor-release), etc. The time-resolved diagnostics include point- and line-imaging velocity interferometers (VISARs), and transient imaging displacement interferometer (TIDI) for two-dimensional out-of-plane displacement measurement. Data with simultaneous VISAR and TIDI measurements have been acquired on ECAE Be-Cu, rolled Be foils and (0001) single crystal Be. For example, an ECAE Be-Cu sample with an initial roughness of $<$30 nm (the surface opposite to the drive side) was loaded into the plastic regime with a peak stress of $\sim$4.5 GPa during Taylor-release-type confined ablation. The flow stress was found to be about 1.9 GPa from VISAR measurements, and the roughness was about 300 nm shortly after breakout.

NP8.00040 Stability study of planar targets using standard and adiabat shaping pulses , MARINA OLAZABAL-LOUME, CELIA Universite Bordeaux I Talence, LUDOVIC HALLO, CELIA Universite Bordeaux I — It has been recently proposed to reduce the ablative Rayleigh-Taylor instability growth by using the adiabat shaping technics. In this work, the relaxation adiabat shaping scheme [B. Betti et al., Phys. Plasmas 12, 042703 2005] is considered. A prepulse is followed by a relaxation period, when the laser is turned off. We report here a parametric study of picket's parameters carried out with a code dedicated to the linear stability analysis, on the basis of spherical realistic simulations including full physics. It is shown that the set picket/relaxation time mainly determines the target stability and that the adiabat shaping scheme modifies the perturbed state before and at the beginning of the main acceleration. Consequences of small laser pulse shape variations on the target hydrodynamics and on perturbations behaviour are studied.

NP8.00041 Progress Toward Kelvin-Helmholtz instabilities in a High-Energy-Density Plasma on the Nike Laser[1] , E.C. HARDING, R.P. DRAKE, U. of Michigan, Y. AGLITSKIY, NRL Washington, DC, V.V. DWARKADAS, U. of Chicago, R.S. GILLESPIE, M.J. GROSSKOPF, C.M. HUNTINGTON, N. GJECI, D.A. CAMPBELL, D.C. MARION, U. of Michigan — In the realm of high-energy-density (HED) plasmas, there exist three primary hydrodynamic instabilities: Rayleigh-Taylor (RT), Richtmyer-Meshkov (RM), and Kelvin-Helmholtz (KH). Although the RT and the RM instabilities have been observed in the laboratory, no experiment to our knowledge has cleanly diagnosed the KH instability. While the RT instability results from the acceleration of a more dense fluid into a less dense fluid and the RM instability is due to shock deposited vorticity onto an interface, the KH instability is driven by a lifting force generated by velocity shear at a perturbed fluid interface. Understanding the KH instability mechanism in HED plasmas will provide essential insight into detailed RT-spike development, mass stripping, many astrophysical processes, as well as laying the groundwork for future transition to turbulence experiments. We present 2D simulations and data from our initial attempts to create a pure KH system using the Nike laser at the Naval Research Laboratory.

[1]This research was sponsored by the Naval Research Laboratory through contract NRL N00173-06-1-G906 and by NNSA through DOE Research Grant DE-FG52-04NA00064.

NP8.00042 Studies of the ablative Rayleigh-Taylor instability in high-gain direct-drive inertial-confinement-fusion targets[1] , JASON BATES, A.J. SCHMITT, S.P. OBENSCHAIN, D. COLOMBANT, S.T. ZALESAK, D.E. FYFE, U.S. Naval Research Laboratory — In this poster presentation, we report on continuing numerical studies of the hydrodynamic stability of inertial-confinement-fusion targets using the massively- parallel radiation-hydrocode FAST. Our attention is focused on a particular class of "high-gain" direct-drive targets that are irradiated with approximately 1.2 MJ of KrF laser light, and have fusion energy yields about 100 times that value according to one- dimensional simulations. We utilize several different temporally-varying laser pulses with and without "spikes," and examine the two-dimensional stability and gain characteristics for each. Both single-mode and broad-band outer-surface perturbations are considered, and their evolution is compared to theoretical predictions based on ablative-Rayleigh-Taylor growth models.

[1]This work was supported by the U.S. Department of Energy.

NP8.00043 Pre-imposed ripple evolution on planar CH targets with a high-Z overcoat , MAX KARASIK, Y. AGLITSKIY, SAIC, McLean VA, V. SERLIN, J.L. WEAVER, J.W. BATES, Naval Research Laboratory, Washington DC — It has been found previously that a thin (400-800$\AA$) high-Z overcoat on the laser side of the target can be effective in suppressing laser imprint [S. P. Obenschain et al. Phys. Plasmas 9, 2234 (2002)]. In those and subsequent experiments, it was found that the overcoat also results in an apparent delay in growth of a front-surface pre-imposed sinusoidal ripple without affecting the RT growth rate. The cause of this apparent delay is hypothesized to be a change in the ablative Richtmyer-Meshkov (RM) phase of the ripple evolution, which forms the seed for the subsequent RT growth, due to the initial x-ray ablation with the high-Z overcoat. In order to investigate this effect, experiments are performed with a pre-imposed ripple amplitude large enough to be observable from the beginning of the laser pulse. Evolution of the ripple due to ablative RM oscillation and transition to RT growth is then observed by face-on x-ray radiography using Bragg reflection from a curved crystal coupled to an x-ray streak camera. X-ray flux from the high-Z overcoat is monitored using absolutely calibrated time-resolved x-ray spectrometers. Simultaneous side-on radiography using a curved crystal allows target trajectory measurement for comparison with simulations. This work is supported by US DOE/NNSA.

NP8.00044 Simulation of Thin-Shell Capsule Compression in a Hohlraum with Diagnostic Ports[1] , MARK SCHMITT, ROBERT GOLDMAN, Los Alamos National Laboratory, ROBERT KIRKWOOD, Lawrence Livermore National Lab — Observation of the compression of thin spherical shells ("thin-shells") is currently being pursued as a method to determine the early-time radiation drive symmetry inside laser-driven hohlraums for the National Ignition Campaign. Observation of thin shell symmetry during implosion requires x-ray backlighting of the capsule, typical performed through diagnostic holes placed near the waist of the high-atomic-number (e.g. gold) hohlraum. Radiation losses through these holes reduce the temperature inside the hohlraum and introduce additional asymmetry (beyond that from the laser drive) in the radiation environment. Simulations to assess the effects of laser drive and diagnostic holes on capsule implosion symmetry have been performed. We compare the results of these simulations to experiments performed on the Omega laser.

[1]Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

NP8.00045 Techniques to determine electron and ion temperatures in D2/3He filled capsules , M.A. GUNDERSON, D.C. WILSON, J.F. BENAGE, G.A. KYRALA, L.A. WELSER-SHERRILL, H. MAKARUK, Los Alamos National Laboratory, C.K. LI, J. FRENJE, R. PETRASSO, Massachusetts Institute of Technology, B. YAAKOBI, Laboratory for Laser Energetics, W. GARBETT, AWE — In order to match yields in ICF implosion experiments, the ability to determine temperatures in the imploded capsules is crucial. "Mix" is commonly used to adjust the simulation to match the experimental yield, but to be more confident that the mix model is being applied correctly, it is very important to know the temperature of the imploded fuel region. To acquire information on ion temperatures in the imploded fuel, we have neutron time-of-flight data, proton spectroscopy, and the ratio of D+3He proton to D+D neutron yield. To determine electron temperatures, we have spectral emission data from spectroscopic tracers (Krypton, Argon) and the slope and shape of the continuum spectrum. In fact, the spectral emission data can also be used to determine the density in the imploded fuel. A summary of the temperature measurements using these techniques will be presented. Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

NP8.00046 HYDRA simulations of Ar-doped gas filled capsules for ICF studies , MEHUL PATEL, SAM DALHED, MICHAEL MARINAK, Lawrence Livermore National Laboratory — In ICF-related experiments, emission spectra from mid-Z dopants such as Ar and Ne can be used to characterize the temperature and electron density in the compressed DT (or DD) gas. The neutron yield from Ar-doped capsules observed during Omega experiments was significantly lower than predicted by initial rad-hydro simulations. Subsequent Lasnex simulations using improved non-LTE (LTE= local thermodynamic equilibrium) atomic models, showed better agreement. We will describe the non-LTE detailed configuration accounting (DCA) model that has been incorporated into HYDRA. A first application of this new capability is to extend the earlier work on understanding the yields and temperatures inside doped capsules. Results from new HYDRA simulations will be presented in the context of previous simulations, OMEGA experiments, and NIF-scale capsules.

Work performed under the auspices of the U.S. DOE at the University of California/Lawrence Livermore National Laboratory under contract W-7405-ENG-48

NP8.00047 Low velocity ion stopping in multicomponent plasmas for WDM production , BEKBOLAT TASHEV, kazNu Almaty, CLAUDE DEUTSCH, LPGP UParis, TASHEV COLLABORATION — In order to comply with several converging international endeavors (Berkeley, Darmstadt, Princeton...) aiming at heating thin solid foils into warm dense matter(solid density and eV temperature range)through the impact of intense and low velocity ion beams we focus our attention on multispecies target.Collisional and dielectric approaches are contrasted in the Bragg peak region of current operational interest.We evidence a critical ion projectile velocity Vp such as target electron stopping turns comparable to target ion stopping.Various simplifying approximations qualifying target ion stopping are thus thoroughly compared. The given critical velocity being somewhat reminiscent of an equivalent one in MFE associated with tokamak anomalous heating,we extend our investigation to the heating of magnetized targets as well.

NP8.00048 Simulations of ion beam heated targets for warm dense matter (WDM) physics and inertial fusion energy[1] , J. BARNARD, A. FRIEDMAN, M. MARINAK, LLNL, L.J. PERKINS, J. ARMIJO, F. BIENIOSEK, E. HENESTROZA, M. LEITNER, B.G. LOGAN, R. MORE, P. NI, G. PENN, P. ROY, P. SEIDL, J. WURTELE, A. ZEBALLOS, A. ZYLSTRA, LBNL, R. DAVIDSON, L. GRISHAM, I. KAGANOVICH, PPPL, C. DEBONNEL, CEA/DIF, P. STOLTZ, S. VEITZER, Tech-X — We present simulations and analysis of ion beam heating of foil targets in the WDM regime for prospective experiments on the Neutralized Drift Compression Experiment (NDCX-1) and its proposed upgrade (NDCX-II). The simulations were carried out using the multi-physics rad/hydro code HYDRA[2], as well as the 1D codes DPC[3]and DISH[4]. Calculations of droplet radius evolution and ion energy deposition refinements were carried out. Initial simulations of direct drive capsules using temporally tailored ion beams will also be presented. [2]M. M. Marinak, et al, Phys. Plasmas **8**, 2275 (2001); [3]R. More, et al, JQSRT **99**, 409 (2006); [4]DISH is a Deeply Simplified Hydrodynamics code authored by R. More, June 2007.

[1]This research was performed under the auspices of the U.S. DOE by UC, LLNL and LBNL under Contract Numbers DE-AC03-76SF00098 and W-7405-Eng-48, and by PPPL under DEAC02- 76CH03073.

NP8.00049 Heavy-ion direct-drive T-lean targets for self-T breeding and plasma MHD direct conversion[1] , B. GRANT LOGAN, Lawrence Berkeley National Laboratory, L. JOHN PERKINS, KAI N. LAFORTUNE, JOHN J. BARNARD, Lawrence Livermore National Laboratory — Transverse and longitudinal beam compression in neutralizing plasma enable heavy ion beam direct drive in the ablative rocket regime at high rocket efficiency with ion ranges a fraction of the initial ablator thickness for low adiabat implosions. Ions can couple energy into thick fuel capsule ablators at the peak in rocket efficiency as efficiently as x-rays do in hohlraums, but without conversion loss of beam energy into x-rays. High ablation velocities with heavy ion direct drive mitigate hydrodynamic instabilities like x-ray drive. An analytic implosion model with a heavy-ion dE/dx deposition model, together with hydrodynamic implosion calculations (LASNEX and HYDRA) explore beam requirements for heavy ion direct drive for small 1 MJ drive DT targets and larger Tritium-lean ($>$ 90% DD) targets. Both model and implosion codes indicate ion beams can couple $>$15% of their incident energy into compressed fuel assemblies. Increasing ion energy during the drive pulse can reduce the parasitic beam losses on ablated plasma.

[1]Auspices of the U.S. DOE by Lawrence Berkeley National Laboratory under Contract Number DE-AC03-76SF00098 and W-7405-Eng-48.

NP8.00050 Process Model of the Gas Recovery System in an IFE reactor , CHARLES GENTILE, MARIA ARISTOVA, Princeton Plasma Physics Laboratory — It is necessary to develop a detailed representative model for the fuel recovery system (FRS) in the prospective direct drive inertial fusion energy (IFE) reactor. In order to observe the interaction of all components, a chemical process model is developed as part of the conceptual design phase of the project. Initially, the reactants, system structure, and processes are defined using the known contents of the vacuum vessel exhaust. The output, which will include physical properties and chemical content of the products, is analyzed to determine the most efficient and productive system parameters. The results of the modeling will be presented in this paper. This modeling exercise will be instrumental in optimizing and closing the fusion fuel cycle in the IFE power reactor.

NP8.00051 Possible Radiochemical Signatures for Imploding Capsule Diagnostics on the National Ignition Facility[1] , CHARLES CERJAN, MARK STOYER, ROB HOFFMAN, PETER AMENDT, JEFF COLVIN, Lawrence Livermore Natl Lab — One of the most important and challenging issues confronting capsule implosion experiments will be a quantitative evaluation of the implosion dynamics. Given the extreme conditions under which these experiments will occur, developing robust, sensitive diagnostics will be difficult. Radiochemical signatures might provide important insight into material mixing and laser drive asymmetry that would complement planned x-ray and nuclear diagnostics since the relevant nuclear reactions sample the core conditions directly. Simulations of both single-shell and double-shell target configurations with selected radiochemical tracers indicate that several experimentally accessible isotopic ratios would be suitable diagnostics for the expected implosion conditions.

[1] This work was performed under the auspices of U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

NP8.00052 Simulating Mono-energetic Proton Radiographs of Inertial Confinement Fusion Experiments using the Geant4 Monte Carlo Particle Transport Toolkit , M.J.-E. MANUEL, F.H. SEGUIN, C.K. LI, J.R. RYGG, J.A. FRENJE, R.D. PETRASSO, MIT PSFC, R. BETTI, O. GOTCHEV, J. KNAUER, F. MARSHALL, D.D. MEYERHOFER, V.A. SMALYUK, UR LLE — Proton radiography has been used to image Inertial Confinement Fusion (ICF) capsules during their implosions as well as to quantitatively measure magnetic fields generated by laser-plasma interactions at the OMEGA laser facility. An imploded, D^3He-filled capsule provides mono-energetic, $\sim$15-MeV protons for radiographing another capsule. We are developing simulated models of these experiments using the Geant4 Monte Carlo Particle Transport Toolkit (G4). Of particular interest are the limitations on spatial resolution caused by scattering effects. Experimental and simulated results will be presented for different experiments and models. This work was performed in part at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE, LLNL, LLE and FSC at Univ. Rochester.

NP8.00053 The CR-39 Coincidence Counting Technique for Enhanced Signal-to-Background in a Large Range of Charged-Particle and Neutron Measurements at OMEGA and the NIF , D.T. CASEY, J.A. FRENJE, S.C. MCDUFFEE, C.K. LI, J.R. RYGG, F.H. SEGUIN, R.D. PETRASSO, MIT PSFC, V.YU. GLEBOV, D.D. MEYERHOFER, S. ROBERTS, T.C. SANGSTER, UR LLE — CR-39 detectors have been used extensively in several types of nuclear diagnostic applications for diagnosing Inertial Confinement Fusion plasmas produced at the OMEGA laser facility. A coincidence counting technique (CCT) is now being used to identify particle tracks in CR-39 when large background noise levels are present, such as when measuring products of secondary reactions. Two orders of magnitude improvement in the signal to background ratio can be achieved in some applications. In this paper, we describe the effect of the CCT when applied to a large range of charged-particle and neutron data obtained from measurements performed at OMEGA and for proposed work at the NIF. This work was supported in part by the U.S. Department of Energy (Grant No. DE-FG03-03SF22691), LLE (subcontract Grant No. 412160-001G), LLNL (subcontract Grant No. B504974).

NP8.00054 NIF Conceptual Design Studies of Bang Time Diagnostics Using d-t Fusion Gamma Rays[1] , JOSEPH MACK, CARLTON YOUNG, SCOTT EVANS, HANS HERRMANN, Los Alamos National Laboratory, ROBERT MALONE, National Securities Technologies, MICHAEL MORAN, VLADIMIR GLEBOV, University of Rochester, Laboratory for Laser Energetics — Bang time and reaction history measurements are essential components of diagnosing failure-modes for ICF implosions on the National Ignition Facility (NIF). Fusion gamma rays are the preferred observable, as they offer the most direct link to deuterium-tritium (d-t) burn. NIF requirements dictate time resolution and timing accuracy of <10 ps and <50 ps, respectively. Current approaches use Gas Cherenkov Detectors (GCDs) that convert d-t fusion gamma rays to optical Cherenkov photons, which are collected and recorded by an appropriately fast system. GCD systems, based on ultra-fast photomultiplier tubes and streak cameras, have been developed and fielded successfully at the Omega laser facility. A comparative study of streak-camera-based designs, using optical transport and light pipes, are presented. Trade-off analyses are provided based on achievable throughput and bandwidth. Related studies are also described that attempt to optimize the most advantageous aspects of the case studies.

[1]Sponsored by U. S. DoE/ LANS, LLC, Los Alamos National Laboratory, LA-UR-07-4522.

NP8.00055 A Neutron Streak Camera Designed for ICF Fuel Ion Temperature , JIABIN CHEN, HUA LIAO, MING CHEN, National Key Laboratory of Laser Fusion, Reseach Center of Laser Fusion, China Academy of Engineering Physics — A neutron streak camera was designed for inertial confinement fusion (ICF) fuel ion temperature diagnostic. It is made of a 1 cm thick $\times$8 cm diam piece of 3% benzophenone quenched plastic scintillator with about a 190 ps FWHM and a streak tube (55ps time resolution) with large-area photocathode (ϕ30 mm) showed no slit. The electron beam from the photocathode is focused into a little spot (ϕ1mm). Then the spot is scanned directly and multiplied by an internal microchannel plate. This greatly improves the sensitivity of the tube. The neutron streak camera combines the advangtages of scintillation detector (with high neutron detection efficiency) and of streak camera (with fast time response). The whole detection system time resolution is 300ps and can record neutron time of flight signals from ICF implosion target with yields of 10^7 DT neutron per shot.

NP8.00056 Innovative High-Pressure Helium Neutron Detector , G.A. CHANDLER, M.S. DERZON, Sandia National Laboratories — Neutron detection systems are required to provide critical data for inertial confinement fusion experiments at Sandia National Laboratories. Critical measurements include Neutron spectroscopy, Neutron bang-time and Neutron Imaging. Present detector systems including scintillators coupled to photomultipliers, scintillating fiber arrays, diamond photoconductive detectors, and other systems, have been developed for these measurements. These detectors all have their limitations with regards to sensitivity, time response, energy resolution, spatial resolution and background rejection. An innovative high-pressure Helium detector is proposed that appears to have many beneficial performance characteristics with regards to making these neutron measurements in the high bremsstrahlung environments found in high energy density physics experiments on the fast pulsed power facilities at Sandia. Calculations of the performance characteristics of these detectors will be presented. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Dept. of Energy under contract No. DE-AC04-94AL85000.

NP8.00057 Sandia National Laboratories' Z-Petawatt Laser Facility: A Progress Report[1] , G.R. BENNETT, P.K. RAMBO, B.W. ATHERTON, E. BRAMBRINK, A.D. EDENS, M. GEISSEL, J.L. PORTER, J. SCHWARZ, I.C. SMITH, Sandia National Laboratories — Sandia National Laboratories' Z accelerator, which is currently being upgraded and will become operational again 2007, includes the Z-Beamlet Laser (ZBL) system [P. K. Rambo *et al.*, Appl. Opt. **44,** 2421 (2005)] for x-ray imaging support. ZBL is a long-pulse, multi-kJ, TW-class device. For higher energy x-ray requirements on Z, and possible fast ignition studies, an additional laser, the short-pulse, multi-kJ, PW-class Z-Petawatt Laser (ZPW), is presently under construction. In the first phase, 50 J, 0.5 ps pulses have been generated, with pulse compression via commercially-available gratings. In the second phase, with the main cavity slab amplifiers operated at higher gain, followed by beam expansion onto larger (94 cm) Nova gold gratings, an energy enhancement to several hundred J will be achieved. In the final phase, full aperture 4-pass amplification through the main amps, and compression via large multilayer dielectric gratings, will lead to 2 kJ in 1-10 ps.

[1]SAND Number: 2007-4152C. Sandia is a Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the National Nuclear Security Administration under DE-AC04-94AL85000.

NP8.00058 Characterization Studies of Microchannel Plates for Use in High-speed, Time-gated X-ray Cameras[1] , MING WU, CRAIG KRUSCHWITZ, KEN MOY, National Security Technologies, LLC, GREG ROCHAU, Sandia National Laboratories — X-ray detectors based on straight-channel microchannel plates (MCPs) are a powerful diagnostic tool for two-dimensional, time-resolved imaging and time-resolved X-ray spectroscopy in the fields of laser-driven inertial confinement fusion and fast Z-pinch experiments. Understanding the behavior of MCPs as used in such detectors is critical to understanding the data obtained. This presentation reports on recent efforts to characterize MCPs under direct current and pulsed voltage bias and in both saturated and unsaturated regimes. Experiments have been performed using an intense, short-pulse (<1 ps full-width half-maximum) ultraviolet laser. These data are compared to the results of a Monte Carlo code we have developed to describe MCP electron cascade dynamics. We present results from measurements and simulations of MCP gain, saturation behavior, gate profiles, and spatial resolution. In general, good agreement between the experimental data and simulations was obtained.

[1]This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy.

NP8.00059 Supersonic Heat Wave Propagation in Laser-Produced Underdense Plasmas , K.B. FOURNIER, LLNL, Livermore, CA, M. TANABE, H. NISHIMURA, S. FUJIOKA, K. NAGAI, ILE, Osaka University, Japan, A. IWAMAE, Kyoto University, Kyoto, Japan, N. OHNISHI, Tohoku University, Sendai, Japan, F. GIRARD, M. PRIMOUT, B. VILLETTE, D. BABNNEUAU, CEA, Bruyères le Châtel, France, S. MOON, S.B. HANSEN, M. TOBIN, LLNL, Livermore, CA, K. MIMA, ILE, Osaka University, Japan — Intense, multi-keV X-ray sources are required for radiographic applications in laboratory astrophysics and ICF. Low-density targets are favorable for efficient laser-to-X-ray conversion because supersonic energy deposition leads to volumetric heating with low hydrodynamic losses. We report on recent X-ray generation experiments at the GEKKO XII laser. Ti-doped SiO_2 aerogel-filled (3.3 mg/cm^3, 3-6 atom% Ti) Be or CH cylinders were irradiated with nine laser beams with a total of 1 kJ energy in a 2.5 ns square pulse, at 351 nm wavelength. Laser irradiance at the entrance of cylinder was 1.4×10^{14} W/cm^2. The observed heat wave clearly shows two different phases in terms of propagation velocities. The measured heat-front propagation velocity was 1.4×10^{8} cm/s, which is a Mach number of 10 for the given conditions. Electron temperature in the heated target was derived from time-resolved X-ray spectra. By changing observation points, electron temperature profiles of the heat wave along the cylinder axis were obtained at different times.

NP8.00060 X-ray Diagnostic Calibration with a Small Picosecond Laser Facility , C. REVERDIN, M. PAURISSE, A. DUVAL, D. HUSSON, C. RUBBELYNCK, CEA-DIF BP12 91680 Bruyères-le-Chatel France — The broadband x-rays emission of a target irradiated by a laser can be sometimes used to calibrate detectors. X-ray calibration is mainly done in the continuous mode with synchrotron radiation because high intensity monochromatic radiation can be obtained. Such calibration results can be sometimes irrelevant as x-ray plasma diagnostics are operated in pulsed mode (for instance with CVD diamond detectors). At CEA-DIF we have a small picosecond laser facility called EQUINOX with 0.3 J at 800 nm. The laser is focused inside a target chamber on a solid target and produces intense radiation in the 100 eV - 2000 eV range. The x-ray source is routinely monitored with a pinhole camera for the source dimension measurement and with x-ray diodes for the total level flux. In addition an x-ray transmission grating spectrometers, a crystal spectrometer and a single count CCD camera measure the x-ray spectrum between 200 eV and 15 keV. The absolute calibration of those sets of spectrometers allows us full characterised x-ray emission spectra. Typical duration is less than 100ps The spectrum can be adjusted by changing the target material and by x-ray filters. Some examples of calibration will be shown, such as CVD diamonds. . .

NP8.00061 High Dynamic Range Single Shot Third Order Autocorrelator[1] , JOHN MORRISON, ENAM CHOWDHURY, TONY LINK, DUSTIN OFFERMANN, VLADIMIR OVCHINNIKOV, REBECCA WEBER, LINN VAN WOERKOM, RICHARD FREEMAN, The Ohio State University — In experiments involving high power ultra-intense laser interactions with solid targets, characterizing the pre-pulse of the laser pulse is extremely important. The pre-pulse determines the initial conditions of the target onto which the main intense pulse impinges. This information is necessary for accurate experimental analysis and computer simulations for benchmarking efforts and is critical for understanding particle acceleration/transport relevant to Fast Ignition Inertial Confinement Fusion. Current techniques require a large number of shots without significant fluctuations, which are unavailable on low repetition rate lasers. The details of a few to single shot, 10 ps window, third order autocorrelator with high contrast developed on a high power laser will be presented.

[1]Work partially supported by DOE contract number DE-FG-02-05ER54834

NP8.00062 Design of the optical backscatter diagnostic for laser plasma interaction measurements on NIF , J.D. MOODY, P. DATTE, E. NG, K. MAITLAND, W. HSING, B.J. MACGOWAN, D.H. FROULA, P. NEUMAYER, L. SUTTER, N. MEEZAN, S.H. GLENZER, R.K. KIRKWOOD, L. DIVOL, S. ANDREWS, J. JACKSON, A. MACKINNON, I. JOVANOVIC, R. BEELER, L. BERTOLINI, M. LANDON, S. ALVAREZ, T. LEE, LLNL, P. WATTS, NS-Tech — We describe the design of the backscatter diagnostic for NIF laser-plasma interaction (LPI) studies. It will initially be used to validate the 280 eV point design hohlraum and select phase plates for the ignition experiments. Backscatter measurements are planned for two separate groups of 4 beams (a quad). One quad is 30° from the hohlraum axis and the other at 50°. The backscatter measurement utilizes 2 instruments for each beam quad. The full aperture backscatter system (FABS) measures light backscattered into the final focus lens of each beam in the quad. The near backscatter imager (NBI) measures light backscattered outside of the beam quad. Both instruments must work in conjunction to provide spectrally and temporally resolved backscatter power. We describe the design of the diagnostic and its capabilities as well as plans for calibrating it and analyzing the resulting data. This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

NP8.00063 Development of the High Sensitivity Multi Channel Bulk Absorption Laser Calorimeter , CHUNXIAO SU, CUNBANG YANG, WENHONG LI, National Key Laboratory of Laser Fusion, Reseach Center of Laser Fusion, China Academy of Engineering Physics — The ICF experiments performed at Shenguang II facility need to measure the total energy of stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) as well as the weak backscattered SRS and SBS. Generally used laser calorimeter whose sensitivities are rather low, cannot meet the needs of such measurements. Because of long signal cable and AC power disturbance, simply boosting the amplifier gain will lead to the weak signal submerged by noise. Equipped with third order low pass active filters and software smooth filter, the multi channel bulk absorption laser calorimeter introduced in this paper, can significantly restrain the noise. Thus, the sensitivity of laser calorimeter can be greatly improved about two orders higher by means of boosting the amplifier gain than that of the normal type laser calorimeter. Using the new type laser calorimeter in the ICF experiments performed at Shenguang II facility, we obtained results different from that before. The experimental arrangement and the results are presented.

NP8.00064 Electronic Measurement of Microchannel Plate Pulse Height Distribution[1] , C.M. HUNTINGTON, E.C. HARDING, M.E. LOWENSTERN, R.P. DRAKE, University of Michigan — Microchannel plates are a central component to the x-ray framing cameras used in many plasma experiment diagnostic systems. Seeking to improve the photon-to-electron conversion efficiency of x-ray cameras we will characterize the pulse-height distribution of the electron output from a microchannel plate. Replacing the framing camera's phosphor-coated fiber optic screen with a charge-collection plate and coupling to a low-noise multichannel analyzer, we will quantify the total charge generated per photon event over a range of x-ray energies and incident fluxes. Hypothesizing that plate saturation is a function of incident photon flux, we will calculate the saturation regime for microchannel plates operated in a single-plate configuration. The electronically-measured pulse height distribution will be compared to the same data collected via a purely-optical method, as described previously (E. C. Harding and R. P. Drake, Rev. Sci. Instrum. 77, 10E312 (2006)).

[1]This research was sponsored by the Naval Research Laboratory through contract NRL N00173-06-1-G906 and by NNSA through DOE Research Grant DE-FG52-04NA00064.

NP8.00065 C-MOD TOKAMAK —

NP8.00066 Progress and Prospects of Advanced Integrated Scenarios on Alcator C-Mod[1] , A.E. HUBBARD, P.T. BONOLI, C. FIORE, B. LABOMBARD, B. LIPSCHULTZ, Y. LIN, E. MARMAR, R. PARKER, M. PORKOLAB, A.E. SCHMIDT, G. WALLACE, S.M. WOLFE, S. WUKITCH, MIT Plasma Science and Fusion Center, C. KESSEL, J.R. WILSON, ALCATOR C-MOD TEAM — "Advanced" scenarios, with a high non-inductive current and greater degree of control over current and pressure profiles, offer significant potential advantages over conventional tokamak operation. Key issues for application to burning plasmas such as ITER, and for DEMO, include obtaining improved confinement with low external torque and particle sources, and with coupled electrons and ions. External current drive in high confinement plasmas with an edge transport barrier, and compatibility with high divertor heat fluxes, are also important. The Alcator C- Mod integrated scenarios program focuses on addressing these challenges. Key new tools include a lower hybrid current drive system for current profile control and a cryopump for density control. Promising results from recent experiments using both of these will be reported. Modeling shows that scenarios with high non-inductive current fraction are achievable, with increased LHCD power.

[1]Supported by USDoE awards DE-FC02-99ER54512 and DE-AC02-76CH03073

NP8.00067 Simulations and Experiments on Modifying the q-profile for Advanced Tokamak Discharges on Alcator C-Mod[1] , C. KESSEL, S. SCOTT, R. WILSON, PPPL, A. HUBBARD, P. BONOLI, J-S. KO, Y. LIN, R. PARKER, A. SCHMIDT, D. TERRY, G. WALLACE, S. WOLFE, S. WUKITCH, MIT PSFC — As part of the advanced tokamak scenario development on Alcator C-Mod, time-dependent simulations using the Tokamak Simulation Code (TSC) and experiments are examining the impact of ion cyclotron radio frequency (ICRF) heating and Lower Hybrid (LH) heating and current drive on plasma evolution. Here the ICRF heating is obtained by using the hydrogen minority scheme at 80 MHz with BT of 5.4 T. The LH utilizes 4.6 GHz and a phasing of 90 degrees co-CD. Slower plasma current ramps, earlier diverting with heating, H-mode transition, and either ICRF or LH heating, as well as both together, are examined. The sawtooth onset, li, surface voltage, motional stark effect (MSE), and profile data are being used to categorize the impact and constrain the simulations where possible. Experiments have shown that LH powers less than 1/4 of the injected ICRF power can significantly delay the sawtooth onset when injected during rampup. While on the other hand, the ICRF power is found to be critical for accessing the H-mode.

[1]Supported by US DOE Contract No. DE-AC02-76CH03073 and DE-FC02-99ER54512.

NP8.00068 Current Profile Modification By Lower Hybrid Waves in Alcator C-Mod[1] , R.R. PARKER, P.T. BONOLI, A.E. HUBBARD, J. KO, M. PORKOLAB, A.E. SCHMIDT, D.E. TERRY, G.M. WALLACE, S.M. WOLFE, J.C. WRIGHT, MIT PSFC, S.D. SCOTT, J.R. WILSON, PPPL — Driving current off-axis is a prerequisite for realizing steady-state, high-performance Advanced Tokamak (AT) regimes. Lower Hybrid Current Drive (LHCD) is well suited for this purpose since the driven current is typically deposited beyond r/a = 0.5. An important step toward the goal of forming AT regimes with LHCD in Alcator C-Mod is validation of ray-tracing and full-wave codes regarding the location of the LH driven current. In LH experiments on C-Mod, bremsstrahlung produced by fast electrons carrying the RF-induced current indicates that the current is driven off-axis at a location determined by the parallel index of refraction. This is in qualitative agreement with expectation and is supported by indirect evidence such as decreased li, sawtooth stabilization, and changes in q(r) as inferred from MSE. The results will be compared with the predictions of ray-tracing (GENRAY) and full-wave codes (TORIC) coupled with Fokker-Planck codes that follow the self-consistent evolution of f(v).

[1]Supported by USDoE awards: DE-FC02-99ER54512 and DE-AC02-76CH03073.

NP8.00069 Lower Hybrid Coupling Experiments on Alcator C-Mod[1] , G.M. WALLACE, P.T. BONOLI, A.E. HUBBARD, Y. LIN, R.R. PARKER, A.E. SCHMIDT, MIT PSFC, C.E. KESSEL, J.R. WILSON, PPPL — The Alcator C-Mod Lower Hybrid launcher couples RF waves at 4.6 GHz via 4 rows of 22 phased waveguides. Directional couplers in the launcher structure measure forward and reflected power in each waveguide, while six Langmuir probes mounted to the front of the antenna grill monitor density at the plasma edge and act as RF probes for the observation of parametric decay. Parametric decay spectra grow exponentially with line averaged electron density in the regime ω = 3-6 ω_{lh}. Measurements of the coupling of lower hybrid waves have been performed at power levels approaching 1 MW. Edge density, launched $n_{||}$ spectrum, and plasma shape have been adjusted to optimize coupling in Ohmic and ICRF heated L- and H-mode plasmas. Preliminary results show that deleterious effects of ICRF on LH coupling are reduced following boronization, particularly in H-mode. Experimentally observed coupling results will be compared to simulations from a coupling code (M. Brambilla, Nuc. Fus., 16:47-54, 1976.).

[1]Work supported by US DOE awards DE-FC02-99ER54512 and DE-AC02-76CH03073.

NP8.00070 Recent ICRF results on Alcator C-Mod[1] , YIJUN LIN, S. WUKITCH, A. BINUS, A. PARISOT, M. REINKE, MIT, Plasma Science and Fusion Center — Alcator C-Mod utilizes 8 MW ICRF source power in the ion cyclotron range of frequencies (ICRF) to heat plasma in the D(H) or D(He3) minority regimes. The power is injected via two 2-strap and one 4-strap antennas. Recently, we have installed a fast ferrite tuning (FFT) system on one of the 2-strap antennas. The FFT system was shown to maintain the transmitter matchings to antenna loading in a variety of plasmas, L-mode, H-mode, ELMs and pellet injection, with power reflection less than 3%. It can handle forward RF power up to 0.9 MW in typical H-mode plasmas. To understand the role ICRF sheaths play in impurity penetration, discharges with different magnetic topologies will be compared and presented. We will also report on experiments where sawtooth control in the presence of energetic ions is performed utilizing mode conversion current drive. For central seed current in advanced tokamak discharges, fast wave heating and current drive is a candidate scenario and modeling and initial experimental investigations will presented. Finally, new modeling and preliminary experimental result on the synergy between the mode converted IBW and lower hybrid current drive will also be presented.

[1]Work supported by US DoE award No. DE-FC02-99ER5451.

NP8.00071 Collisionality dependence of density peaking in H-mode plasmas in Alcator C-Mod[1] , D.R. MIKKELSEN, Princeton University, M. GREENWALD, MIT, J. CANDY, R. WALTZ, General Atomics — Recent results from Alcator C-Mod confirmed earlier AUG and JET findings that spontaneous peaking of the density profile in H-mode plasmas depends on collisionality. Quasi-linear transport estimates based on gyrokinetic stability calculations (C. Angioni, et al., Phys. Plasmas 12, (2005) 112310) found a pinch that was restricted to a range of collisionality completely outside the range of experimental data. We will present nonlinear, 'full-radius', gyrokinetic turbulence simulations with experimentally relevant levels of impurities to determine the degree to which these added levels of completeness can bring theory into harmony with experiment. Particular attention will be paid to the significance of including multiple impurity species and two hydrogenic species. We will also explore the sensitivity of the results to the detailed form of the collision operator, including one that is momentum conserving.

[1]Supported by US DOE Contract No. DE-AC02-76-CHO-3073.

NP8.00072 Ohmic ITBs in Alcator C-Mod[1] , WILLIAM L. ROWAN, IGOR O. BESPAMYATNOV, Fusion Research Center, The University of Texas at Austin, C.L. FIORE, A. DOMINGUEZ, A.E. HUBBARD, A. INCE-CUSHMAN, M.J. GREENWALD, L. LIN, E.S. MARMAR, M. REINKE, J.E. RICE, K. ZHUROVICH, MIT-PSFC — Internal transport barrier (ITB) plasmas can arise spontaneously in Ohmic Alcator C-Mod plasmas. The operational prescription for the ITB include formation of an EDA H-mode in a toroidal magnetic field that is ramping down and a subsequent increase in the toroidal magnetic field. Like ITBs generated with off-axis ICRF heating, these have peaked pressure profiles which can be suppressed by on-axis ICRF heating. Recent work on onset conditions for the ICRF generated ITB (K. Zhurovich, et al., To be published in Nuclear Fusion) demonstrates that the broadening of the ion temperature profile due to off-axis ICRF reduces the ion temperature gradient and suppreses the ITG instability driven particle flux as the primary mechanism for ITB formation. The object of this study is to examine the characteristics of Ohmic ITBs to find whether this model for onset is supported.

[1]Supported by USDOE Grants DE-FG03-96ER54373 and DE-FC02-99-ER54512

NP8.00073 The role of turbulent suppression in the triggering ITBs on C-Mod[1] , K. ZHUROVICH, MIT-PSFC, C.L. FIORE, D.R. ERNST, P.T. BONOLI, M.J. GREENWALD, A.E. HUBBARD, J.W. HUGHES, E.S. MARMAR, D.R. MIKKELSEN, PPPL, P. PHILLIPS, FRC, J.E. RICE — Internal transport barriers can be routinely produced in C-Mod steady EDA H-mode plasmas by applying ICRF at |r/a| $\geq$ 0.5. Access to the off-axis ICRF heated ITBs may be understood within the paradigm of marginal stability. Analysis of the T_e profiles shows a decrease of R/L_{Te} in the ITB region as the RF resonance is moved off axis. Ti profiles broaden as the ICRF power deposition changes from on-axis to off-axis. TRANSP calculations of the T_i profiles support this trend. Linear GS2 calculations do not reveal any difference in ETG growth rate profiles for ITB vs. non-ITB discharges. However, they do show that the region of stability to ITG modes widens as the ICRF resonance is moved outward. Non-linear simulations show that the outward turbulent particle flux exceeds the Ware pinch by factor of 2 in the outer plasma region. Reducing the temperature gradient significantly decreases the diffusive flux and allows the Ware pinch to peak the density profile. Details of these experiments and simulations will be presented.

[1]Work supported by USDoE awards DE-FC02-99ER54512, DE-AC02-76CH03073, ED-FG03-96ER54373.

NP8.00074 Low Density ITB Studies Using the Upgraded C-Mod Reflectometry System[1] , A. DOMINGUEZ, E. EDLUND, C.L. FIORE, L. LIN, E.S. MARMAR, J.A. SNIPES, M. PORKOLAB, PSFC MIT, G.J. KRAMER, PPPL, W.L. ROWAN, FRC UT AUSTIN, PSFC MIT TEAM, PPPL COLLABORATION, FRC UT AUSTIN COLLABORATION — The Alcator C-Mod reflectometry system was recently upgraded in two ways: The low frequency channels were changed from amplitude modulation - in which two microwave signals, slightly separated in frequency, are injected into the plasma - to baseband, where a single frequency is used, in order to improve density fluctuation measurements. The second change, a variable frequency channel operating over the range from 122GHz to 140GHz (with corresponding density cutoffs of 1.84-2.43x10^{20}m^{-3}) has been installed in collaboration with PPPL. Initial results from the upgraded system are presented, including the study of low density Internal Transport Barriers. Using O-mode waves, the reflectometry system is able to radially localize density fluctuations on the low field side along the tokamak midplane. It can, therefore, be used to probe the foot of low density ITBs. The corresponding reflectometry data will be compared to those of other fluctuation diagnostics, including Phase Contrast Imaging and magnetic pick-up coils.

[1]Supported by USDoE award DE-FC02-99ER54512.

NP8.00075 Localized Temperature Scale Length Measurements in Alcator C-Mod With Central RF Heating[1] , PERRY PHILLIPS, KENNETH GENTLE, WILLIAM ROWAN, Fusion Research Center, Univ. of Texas — The electron temperature scale length $L_{T_e} = {}^{T_e}/_{\nabla T_e}$ can be measured locally using ECE and small ${}^{\Delta B}/_{B} \approx 1\%$ changes in toroidal field. These measurements are extremely useful because they have high accuracy, are independent of the ECE calibration and they can have high spatial resolution. Alcator C-Mod has the ability to rapidly change the toroidal field to allow these measurements. The heterodyne ECE system on Alcator C-Mod has 32 closely spaced channels ($\Delta R \approx 7mm$)allowing very high spatially resolved temperature and L_{T_e} profiles. The experiments were conducted with central RF heating that allowed variation of the heat flux in the confinement region. This heat flux may then be compared to the changes in the L_{T_e} as the RF power is varied. L_{T_e} is a key parameter in investigation of heat transport and the role of a turbulence threshold above a critical gradient that results in profile stiffness. Results will be presented in this poster.

[1]Supported by USDoE contract ED-FG03-96ER54373.

NP8.00076 Drift Wave Turbulence Studies with the Phase Contrast Imaging Diagnostic in Alcator C-Mod[1] , L. LIN, M. PORKOLAB, E.M. EDLUND, D.R. ERNST, M. GREENWALD, N. TSUJII, MIT PSFC — The Phase Contrast Imaging diagnostic (PCI) in Alcator C-Mod has measured density fluctuations with frequencies up to 500 kHz and wavenumbers up to 20 cm^{-1}, which corresponds to $k_R\rho_s$~1.6. Furthermore, as the density increases in ohmic plasmas, the observed relative density fluctuation level decreases in the "linear" ohmic regime (low density, Alcator scaling, $\tau_{kin} \propto n_e$), whereas it increases in the high density "saturated" ohmic regime. Recent upgrades have enabled the PCI system to localize the short wavelength turbulence in the ETG range and resolve the direction of propagation (i.e., electron vs. ion diamagnetic direction) of even the longer wavelength turbulence in the ITG/TEM range. Initial analysis of the observed turbulence in purely ohmic plasmas indicates that $|\tilde{n}_+/\tilde{n}_-|$ in the frequency range of 100-400 kHz and wavenumber range of 2-8 cm^{-1} decreases monotonically but remains above 1.0 as the density is reduced. Here $\tilde{n}_+/\tilde{n}_-$ is the ratio of density fluctuations propagating in the ion diamagnetic direction to those propagating in the electron direction. We will compare these measurements with gyro-kinetic code predictions (e.g., GS2, GYRO).

[1]Work supported by U. S. DOE under DE-FG02-94-ER54235 and DE-FC02-99-ER54512.

NP8.00077 Impurity poloidal rotation and other CXRS measurements for $0.1 < \rho < 1.0$ in Alcator CMod plasmas.[1]

, IGOR BESPAMYATNOV, WILLIAM ROWAN, KENNETH GENTLE, The University of Texas at Austin, Fusion Research Center, ROBERT GRANETZ, DEXTER BEALS, MIT Plasma Science and Fusion Center — The new wide-view poloidal CXRS array was installed and successfully tested during the CMod's 2007 experimental campaign. The 19 new poloidal chords traverse the outer half of the CMod plasma allowing measurement of B^{+5} rotation, temperature, and density profiles for $0.1 < \rho < 1.0$. Along with the toroidal flow velocity measured by the toroidal CXRS array, these measurements are sufficient to investigate the validity of neoclassical theory. This work focuses on the top of the plasma pedestal $0.5 < \rho < 0.90$, where neoclassical theory is expected to be applicable and where the maximum CXRS enhancement is observed. Our previous study showed that the region of the plasma edge $0.90 < \rho < 1.0$, contained high density and temperature gradients that vary during the L to H mode transition so that comparison with neoclassical theory is very difficult. Radial electric field profiles will also be presented. The changes of the impurity rotation profiles and E_r evaluation play a role in understanding of the physics of the L to H transition.

[1]Work supported by USDOE Grant DE-FG03-96ER54373 and Coop. Agree. No. DE-FC02-99-ER54512.

NP8.00078 Impurity Temperature and Velocity Profiles in L-mode and H-mode from the New Edge Charge Exchange Diagnostic on Alcator C-Mod[1]

, R.M. MCDERMOTT, B. LIPSCHULTZ, K. MARR, D. WHYTE, J.W. HUGHES, PSFC, MIT — The edge Charge Exchange Spectroscopy (CXS) system on Alcator C-Mod has been upgraded to include a beam viewing toroidal periscope. This periscope is designed to work in conjunction with the pre-existing edge poloidal CX periscope enabling concurrent measurements of the poloidal and toroidal velocity as well as the temperature and density of the B^{+5}ions in the edge pedestal region ($0.8 < r/a < 1.08$). Temporally resolved radial profiles of B^{+5}brightness, temperature, and velocity have been obtained in both L and H mode plasmas. Although the time resolution of the edge CXS diagnostic (6.2ms) is not sufficient to capture the evolution of edge profiles during standard L-H transitions, the temperature profiles obtained before and after the transition show excellent agreement with electron temperature measurements from the edge Thomson Scattering diagnostic. The obtained velocity profiles indicate that the poloidal velocity is the dominant term in the calculation of E_r and H-mode poloidal velocity profiles indicate strong E_r shear just inside the last closed flux surface.

[1]Work supported by USDOE Coop. Agree. No. DE-FC02-99-ER54512 to MIT.

NP8.00079 Velocity measurements from the pedestal-viewing CXRS system on Alcator C-Mod[1]

, KENNETH MARR, BRUCE LIPSCHULTZ, RACHAEL MCDERMOTT, Plasma Science and Fusion Center — The evolution of velocity profiles can be used to study the toroidal momentum transport and shear that purportedly play an important role in the formation and intensity of the H-mode. For the 2007 run campaign the charge-exchange spectroscopy diagnostic has been upgraded for better spatial and temporal resolution of the pedestal region of the plasma. The 'pedestal' is the area near the separatrix where the density forms a steep gradient during H-mode. The diagnostic utilizes injected neutrals at both the high- and low-field edges of the plasma to spatially localize the measurement of toroidal and poloidal velocities at the intersection of the line of sight with the beam of injected neutrals. The upgrade added more views of the plasma, including background (away from the injection) views, and new spectrometers. Measured velocities trend as expected; increasing in magnitude into H-mode and into the core. These results are compared to similar diagnostics on Alcator C-Mod and their relation to momentum transport is discussed. Specific focus will be on v and Ti profile evolution during the transition from L- to H-mode.

[1]Supported by USDoE award **DE-FC02-99ER5451

NP8.00080 Inference of Ion-Temperature and Rotation-Velocity Profiles from a Spatially Resolving X-Ray Crystal Spectrometer on Alcator C-Mod[1]

, K.W. HILL, M. BITTER, PPPL, P. BEIERSDORFER, LLNL, A. INCE-CUSHMAN, MIT, MING-FENG GU, LLNL, S.G. LEE, NFRC, Korea Basic Science Inst., M. REINKE, J.E. RICE, MIT, S.D. SCOTT, PPPL — A new x-ray crystal spectrometer capable of providing spatially (~1.5 cm) and temporally (~10 ms) resolved, high resolution spectra of He-like Ar Kα lines has been installed on Alcator C-Mod. The imaging spectrometer consists of a spherically bent crystal and three Pilatus II 2d pixel detectors. Spectra are simultaneously measured from 12 – 45 chords covering the region r/a = 0 - 0.8 with count rates of 0.1 – 5.0 MHz per chord, enabling measurement with good statistics. Preliminary ion-temperature (T_i) and rotation-velocity (v_ϕ) profiles are inferred from the Doppler widths and shifts of the chordally integrated spectral lines. The data analysis techniques, T_i and v_ϕ profile results, analysis of background resulting from fusion neutrons, and predictions of performance on ITER and other tokamaks will be presented.

[1]Research supported by U.S. DOE contract DE-AC02-76-CH03073.

NP8.00081 Application of new fitting routines on edge Thomson scattering profiles from Alcator C-Mod[1]

, N. GIERSE, University of Cologne, J.W. HUGHES, B. LABOMBARD, B. LIPSCHULTZ, MIT PSFC — The edge plasma region plays a key role in the performance of tokamak fusion devices, as transport in this region directly affects the energy confinement properties of the discharge and determines particle and heat loads on the first wall and the divertor. Recent experiments in Alcator C-Mod show strong evidence that transport in edge is governed by critical gradients physics in both L-mode and H-mode. To examine profiles from experimental millimeter resolution Thomson scattering edge data a modified tanh fit is routinely performed which reports the global pedestal parameters. The goals of this work are to apply new fitting techniques (e.g. B-splines), and then compare results to find the most suitable fitting routine which does not impose artificial constraints on the result. The results of such fits for a wide variety of L- and H-mode profiles are then stored in a recently constructed database with complete profile information. This allows us to conduct profile studies over a wide range in C-Mod operation space and over a range of radial locations in the edge region.

[1]Supported by USDoE award DE-FC02-99ER54512.

NP8.00082 Results From Stereoscopic Imaging of the Ablation of Injected Li Pellets in the Alcator C-Mod Tokamak.[1]

, B. BOSE, E. MARMAR, PSFC, D. MIKKELSEN, PPPL, M. GREENWALD, PSFC, S. ZWEBEN, PPPL — Using an ultra high speed CCD camera, (frame rate up to 500 kHz) and a stereoscopic imaging system the detailed three dimensional evolution of striations formed in lithium plasma during the ablation of injected lithium pellets has been recorded on the Alcator C-Mod tokamak. The striations move primarily in the poloidal direction during the first 10 μs after their formation and show distinctly different behaviors in ohmic L-mode plasmas and ICRH heated H-mode plasmas. During ohmic L-mode plasmas the direction in which the striations are emitted oscillates from the positive to negative ion diamagnetic direction on a length scale of 10-20 ion gyro radii, and they move with speeds of up to 5 km/s. On the other hand, during ICRH heated H-mode plasmas the striations show a distinct propensity to be emitted in the negative ion diamagnetic direction, and again move with speeds of up to 5 km/s. The measured characteristics of the striations will be compared with the theoretical predictions of Parks' striation theory [1]. In addition we are exploring possible correlations between striation characteristics and properties of self-generated zonal flows within the plasma. [1] Parks PB 1996 Plasma Phys, Contrl. Fusion **38** 571

[1]1Supported by USDoE award **DE-FC02-99ER54512

NP8.00083 Design and operation of a novel divertor cryopumping system in Alcator C-Mod[1]

, B. LABOMBARD, B. BECK, J. BOSCO, R. CHILDS, D. GWINN, J. IRBY, R. LECCACORVI, S. MARAZITA, N. MUCIC, S. PIERSON, Y. ROKHMAN, P. TITUS, R. VIEIRA, J. ZAKS, A. ZHUKOVSKY, MIT Plasma Science and Fusion Center — C-Mod's recently installed upper-divertor cryopump is unique among the world's tokamaks, employing an array of gas-pumping slots that penetrate the upper divertor target. This geometry enables the use of a single toroidal loop of liquid helium, operating in an efficient heat transfer regime with low or no helium flow. A system pumping speed of 9,600 l/sec for D_2 gas has been achieved, matching that of a full-scale prototype system. Neutral pressures in the pumping slots during upper-null plasmas (USN) are found to meet or exceed pressures in the lower divertor's private flux region during lower-null (LSN) – evidence that the pumping-slot geometry is performing as intended. Very high steady-state pumping throughputs (exceeding ~140 torr-l/s) have been demonstrated in USN. Reliable and efficient operation of the pump has been established, synchronized with the C-Mod shot cycle and consuming 60 to 90 liters of liquid helium during a full day of operation.

[1]supported by U.S. DOE Agreement DE-FC02-99ER54512.

NP8.00084 The Instrumental Function of the new X-ray Imaging Crystal Spectrometer on Alcator C-Mod[1]

, M. BITTER, K.W. HILL, D. MIKKELSON, S. SCOTT, Princeton University, A. INCE-CUSHMAN, M. REINKE, J.E. RICE, MIT-PSFC, P. BEIERSDORFER, M.F. GU, Lawrence Livermore National Laboratory — A new high-resolution X-ray imaging crystal spectrometer was installed on Alcator C-Mod to determine the radial profiles of the ion temperature and toroidal plasma rotation velocity from the Doppler widths and Doppler shifts of spectral lines from He- and H-like argon. The instrument consists of two spherically bent crystals and high count rate, semi-conductor diode arrays, so-called PILATUS II detector modules, which are arranged in the Johann configuration. The poster will present analytical and numerical calculations of the instrumental function and the observed spectral line profiles. The results obtained from these calculations will be compared with the experimental data.

[1]supported by DOE contracts: DE-AC02-76CHO3073, DE-FC02-99ER54512, W-7405-Eng-48, and DOE Initiative for Plasma Diagnostic Developments, Contract-1083.

NP8.00085 Spectroscopic Diagnostics using a Visible Transmission Grating Spectrometer at the Alcator C-Mod Tokamak[1]

, A. GRAF, UC Davis, M. MAY, P. BEIERSDORFER, LLNL, D. WHYTE, B. LABOMBARD, N. SMICK, K. MARR, PSFC — A high throughput, f/#~3.5, transmission grating spectrometer for visible light (350-670 nm), is being used to make localized measurements of bulk flow velocities and temperatures of impurity ions and deuterium atoms, in the edge and scrape off layer of C-Mod. The flows and temperatures of the main atoms are investigated by detecting D_β emission from charge exchange recombined deuterons which is enhanced by providing a local atom source from a gas puff. The CCD detector used with the spectrometer allows a simultaneous measurement from 4 different spatial points with a time resolution $\geq$10 ms/frame. Comparison between our results and the edge flows measured by a Mach probe and those from other spectroscopic diagnostics will be given. A higher time resolution (~100 μs/frame) is possible by using a special readout mode of the CCD. This allows time resolved electron density measurements from Stark broadened D_β during disruptions.

[1]This work was performed under the auspices of the US DoE by UC LLNL under contract W-7405-ENG-48 and by the Alcator C-Mod team under contract DE-FC02-99ER054512.

NP8.00086 Effect of secondary beam neutrals on MSE: Experiment[1]

, JINSEOK KO, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA, STEVE SCOTT, Princeton Plasma Physics Laboratory, Princeton, NJ, USA, BILL ROWAN, Fusion Research Center, University of Texas, Austin, TX, USA, BOB GRANETZ, IAN HUTCHINSON, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA, HOWARD YUH, Nova Photonics, Inc., NJ, USA — It has been conjectured that the anomalous results obtained previously during beam-into-gas calibrations of the Motional Stark Effect (MSE) diagnostic on Alcator C-Mod are caused by the 'secondary' beam neutrals - the neutrals that ionize following collisions with the torus gas and then re-charge exchange at a random gyro angle. Based on this conjecture, the C- Mod diagnostic neutral beam (DNB) was pivoted toroidally to impart a non-zero parallel beam velocity. In this new configuration, spectroscopic measurements and beam-into-gas calibrations confirm that the beam-into-gas anomaly is caused by the secondary beam neutrals. In addition, we report initial results from the beam-into-plasma calibration using plasma edge sweeping and plasma current ramping.

[1]Work supported by the U.S. Department of Energy, Grant No. DE-FC02-99ER54512, DE-AC02-76CH03073, and ED-FG03-96ER54373

NP8.00087 Effect of secondary beam neutrals on MSE: Theory[1]

, S. SCOTT, PPPL, J. KO, I. HUTCHINSON, MIT-PSFC, H. YUH, Nova Photonics — A standard calibration technique for Motional Stark Effect (MSE) diagnostics is to compare the polarization direction of Doppler-shifted Hα emission from a diagnostic neutral beam (DNB) that is fired into a gas-filled torus to the pitch angle inferred from known toroidal and vertical fields. However, the polarization direction of Hα emission from 'secondary' beam neutrals that ionize, gyrate about field lines, and then charge exchange a second time differs from the polarization direction of the 'primary' beam neutrals and thus confuses the calibration results. We compute the ratio of secondary-to-primary Hα emission, I_s/I_p, as a function of torus pressure for 50 keV hydrogen atoms in Alcator C-Mod. For helium gas, I_s/I_p is about unity at P=1 mTorr for the DNB in its recently re-oriented configuration (7° from perpendicular). The effect on the MSE calibration of Hα emission from these secondary beam neutrals is calculated by adding the Stokes vectors for all secondary-beam gyro angles whose Doppler shift lies within the MSE filter passband. The computed calibration error increases linearly with torus pressure and has distinct dependencies on MSE viewing geometry and pitch angle which are in qualitative agreement with recent measurements.

[1]Work supported by USDoE awards DE-AC02-76CH03073* and **DE-FC02-99ER54512.

NP8.00088 Design of a new X-mode edge reflectometer for Alcator C-mod[1]

, CORNWALL LAU, MIT Plasma Science and Fusion Center, GREG HANSON, JOHN WILGEN, Oak Ridge National Laboratory, YIJUN LIN, STEVE WUKITCH, MIT Plasma Science and Fusion Center — The study of antenna-plasma interactions during RF heating and current drive often requires high temporal and spatial resolution density profiles of the SOL in front of the ICRF antenna. A new swept-frequency X-mode reflectometer is being built for Alcator C-mod to measure the edge density profiles in front of the future E port antenna. Due to the presence of strong ICRF heating and large density fluctuations, density profile measurements are difficult. This reflectometer is thus designed to use both differential-phase and full-phase reflectometry techniques to allow for the best results to be obtained. The system is planned to operate between 100 and 145 GHz at sweep rates from 10 μs to 1 ms and will cover a density range of approximately 10^{16} to 10^{20} cm^{-3} at 5-5.4 T. Design of this new reflectometer and initial results from modeling and testing will be presented.

[1]Supported by DE-FC02-99ER54512 and DE-AC05-00OR22725.

NP8.00089 Development of Absolute Calibration of the Phase Contrast Imaging Diagnostic and Experimental Tests in Alcator C-Mod[1] , N. TSUJII, M. PORKOLAB, E.M. EDLUND, L. LIN, MIT Plasma Science and Fusion Center — The Phase Contrast Imaging (PCI) system in Alcator C-Mod is used to measure density perturbations from MHD modes, turbulence and RF waves. Recently, an absolutely calibrated system has been installed. This system consists of a set of transducers which cover frequency from 30 kHz to 200 kHz, and wavenumber from 5.5 cm^{-1} to 36.6 cm^{-1}. The amplitude and phase of the transducer wavefronts are measured using a calibrated microphone. We will present the system design and modeling of this calibration system. Initial results, including a comparison with experimental measurements will also be discussed, if available.

[1]Work supported by U. S. DOE under DE-FG02-94-ER54235 and DE-FC02-99-ER54512

NP8.00090 Recent upgrades to Thomson scattering diagnostics on Alcator C-Mod for improved core spatial resolution[1] , Y. MA, J.W. HUGHES, K. ZHUROVICH, A. HUBBARD, MIT PSFC — The Thomson Scattering (TS) diagnostics on C-Mod employ two Nd:YAG lasers, each with a nominal 1.3J, 8ns pulse and 30Hz pulse rate, directed along the same vertical path to measure the electron temperature and density profiles. The core TS diagnostic set has recently been upgraded by adding 8 new compact polychromators in order to deliver core plasma measurements with improved spatial resolution. Up to 16 core detector channels are now available, with each T_e, n_e measurement localized to 4mm in radial coordinates. Optimal positioning of collection fibers concentrates the measurement locations in the internal transport barrier region (typically centered at r/a 0.5), yielding an approximate spatial resolution of 15mm, allowing more accurate study of the plasma gradient scale lengths in this regime. The new polychromators demonstrate high signal-to-noise ratio (S/N) when operated during C-Mod discharges. Calibration results, analysis and plasma measurements will be presented.

[1]Work supported by USDOE award: DE-FC02-99ER54512.

NP8.00091 Real-time Detection of Locked Modes[1] , S. ANGELINI, R.S. GRANETZ, S.M. WOLFE, (MIT) — Disruptions are one of the largest problems facing tokamaks. In a large-scale experiment such as ITER, disruptions would cause crippling damage and severe setbacks in experimentation. One method for disruption mitigation involves the use of a gas jet which has been tested on both normally running plasmas and vertical displacement events (VDEs) on Alcator C-Mod. In both cases, the jet was successful in mitigating disruption effects. The gas jet has not yet been tested on other types of disruptions. Locked-mode major disruptions are easily created in C-Mod and could be used to test the effectiveness of the gas jet as a mitigation method if the jet could be fired early enough. It has been empirically observed that the electron cyclotron emissions (ECE) signal displays a flattening of the normally-present sawteeth before the current quench occurs in certain locked-mode major disruptions. A procedure is being written which will detect the ECE flattening by reading changes in the standard deviation of the signal. This procedure will be programmed into the digital plasma control system (DPCS) for real-time testing.

[1]This work is supported by DE-FC02-99ER54512

NP8.00092 Optimization of gas jet disruption mitigation , ROBERT GRANETZ, DENNIS WHYTE, MATTHEW REINKE, JAMES TERRY, MIT Plasma Science and Fusion Center — Recent experiments on Alcator C-Mod have focused on finding the minimum amount of optimal gas mixture that is required for good disruption mitigation. We desire to reduce the total amount of gas injected into the vessel in order to minimize impact on diagnostics and to shorten the pumpout time between discharges. Previous experiments on C-Mod have shown that a mixture of 15% argon/85% helium optimizes the response time of the gas jet system by increasing the transit speed of the argon, while still realizing good mitigation of halo currents and thermal loads on the divertor surfaces. But those experiments were all done with the plenum pressure set to 70 bar, which results in a undesirably large gas load into the tokamak. It is found that the plenum gas pressure can be reduced substantially, and thus the gas load in the torus, while still maintaining good mitigation characteristics. Results will be presented.

NP8.00093 Kalman Filter for the Real Time Estimation of the Vertical Position of C-Mod Plasmas , M. FERRARA, I. HUTCHINSON, S. WOLFE, J. STILLERMAN, T. FREDIAN, MIT PSFC — A Kalman filter has been implemented for the real-time estimation of the vertical position of C-Mod plasmas. The simulator Alcasim, which reproduces the full evolution of a discharge, is used to synthesize the filter matrices at a time point. The linear model is then employed in the filter for the full duration of the flattop and for different target plasmas, in order to test for robustness. The filter has been extensively tested in linear and full Alcasim simulations. The performance in terms of noise rejection and signal distortion is evaluated in comparison with standard filtering such as lowpass and bandpass. Results show excellent signal tracking and noise rejection. For real-time implementation, computation speed is also a requirement, therefore issues such as off-line training of the filter and linear model reduction are investigated. The experimental test of the filter in the C-Mod fast vertical control loop is expected shortly. This could demonstrate a possible solution to the problem of control degradation and AC losses expected on ITER because of measurement noise. USDoE award DE-FC02-99ER54512.

NP8.00094 Mode structure and stability analysis of reversed shear Alfvén eigenmodes with NOVA-K , ERIC EDLUND, MIKLOS PORKOLAB, LIANG LIN, NAOTO TSUJII, STEVE WUKITCH, MIT Plasma Science and Fusion Center, GERRIT KRAMER, Princeton Plasma Physics Laboratory — Experimental studies of reversed shear Alfvén eigenmodes (RSAEs) with phase contrast imaging (PCI) on the Alcator C-Mod tokamak will be presented. The PCI system measures the line integral of electron density fluctuations along 32 vertical chords passing through the plasma core, and was configured to measure frequencies up to 5 MHz and wavenumbers up to 8 cm^{-1} for these studies. With the PCI system the location of RSAEs can be determined very accurately. In combination with the strong dependency of the RSAE frequency on the minimum value of q this leads to severe constaints for the equilibrium reconstruction of reversed shear discharges. Interpretation of the PCI signals is aided by simulations from NOVA-K calculations of the electron density fluctuations, via a synthetic PCI. This technique has been used to interpret observations of RSAEs during sawteeth and the current ramp-up. Applied to RSAEs during sawteeth, it is found that q reaches a minimum of about 0.97 prior to the crash. NOVA-K calculations of RSAE stability and corresponding constraints on the fast ion population will be presented. *Work supported by US DoE awards DE-FC02-99-ER54512 and DE-FG02-94-ER54235 and DE-AC02-76CH03073.

NP8.00095 Influence of ICRF heating on the stability of TAEs[1] , J. SEARS, W. BURKE, R.R. PARKER, J.A. SNIPES, S. WOLFE, MIT PSFC — Unstable toroidicity-induced Alfvén eigenmodes (TAEs) can appear spontaneously due to resonant interaction with fast particles such as fusion alphas, raising concern that TAEs may threaten ITER performance. This work investigates the progression of stable TAE damping rates toward instability during a scan of ICRF heating power up to 3.1 MW. Stable eigenmodes are identified in Alcator C-Mod by the Active MHD diagnostic. Unstable TAEs are observed to appear spontaneously in C-Mod limited L-mode plasmas at sufficient tail energies generated by > 3 MW of ICRF heating. However preliminary analysis of experiments with moderate ICRF heating power show that TAE stability may not simply degrade with overall fast particle content. There are hints that the stability of some TAEs may be enhanced in the presence of fast particle distribution tails. Furthermore, the radial profile of the energetic particle distribution relative to the safety factor profile affects the ICRF power influence on TAE stability.

[1]Supported by US DoE contract DE-FC02-99ER54512.

NP8.00096 Surface Science Station (S^3): a real-time diagnostic of boronization in Alcator C-Mod[1] , ROMAN OCHOUKOV, BRUCE LIPSCHULTZ, DENNIS WHYTE, NIELS GIERSE, M.I.T., SOREN HARRISON, U. Wisconsin — The recently installed Surface Science Station (S^3) was used to study the effectiveness of boronization utilizing electron cyclotron discharge (ECD) plasmas (90%He 10%D_2B_6) in Alcator C-Mod. The boron (B) deposition was measured in real time with a pair of quartz microbalances (QMBs) the faces of which were oriented parallel and perpendicular to the applied magnetic field. A maximum B deposition rate of ~2.5 nm/min was measured on both QMBs for a chamber pressure of 15 mTorr. The peak deposition took place ~10 cm outboard from the EC resonance. Decreasing the D_2B_6 throughput (pressure) decreased the B deposition rate, again for both QMBs. Overall, the evidence points to the B deposition being primarily ionic and that B ion Larmor radius effects lead to B deposition on surfaces parallel to the magnetic field (implying B ion temperatures in the range of 10-15 eV). Subsequent application of He-only ECDs showed evidence of the B layers being eroded & redeposited by the plasma with rates 10x lower on the QMB face parallel to the magnetic field compared to the QMB face perpendicular to the field.

[1]Supported by USDoE award **DE-FC02-99ER54512

NP8.00097 Diagnostics to Study Flow of Dust Particles in Scrape-Off Layer of Alcator C-Mod Plasmas[1] , AARON BADER, ROBERT GRANETZ, BRIAN LABOMBARD, JAMES TERRY, MIT PSFC — Dust transport and migration is not well understood in tokamaks. Furthermore, current numerical codes (DUSTT) have not been benchmarked with experiments. Interest in dust has increased over recent years as it may be a significant issue in machines with high duty cycles (ITER, DEMO) due to safety concerns. Measuring dust particle trajectories in the plasma can also give added information on Scrape-Off Layer (SOL) flows, since an important force on dust flow is a plasma drag force. In order to study dust particle trajectories in the SOL for different plasma densities and topologies, we have designed and installed a dust injector which injects Boron dust particles into the divertor region. The particles are viewed with a video camera. This provides us with a 2-D projection of the particle trajectories. For full 3-D trajectories we would need to install a second viewing camera. Initial data and results will be presented along with the successes and shortcomings of the diagnostic and future improvements.

[1]This work is supported by USDoE award DE-FC02-99ER54512.

NP8.00098 Stationary ELM-free H-mode on TCV[1] , L. PORTE, S. ALBERTI, E. ASP, A. BORTOLON, A. KARPUSHOV, Y. MARTIN, O. SAUTER, Ecole Polytechnique Federale de Lausanne (EPFL), Centre de Recherches en Physique de Plasmas, Association EURATOM Confédération Suisse — By heating an ohmic ELMy H-mode target using vertically launched 3^{rd} harmonic X-mode ECRH (X3), it was possible to obtain coupled power up to ≈1.3MW which was much greater than the ≈These discharges often transited to an ELM-free H-mode regime with constant electron density and stored energy in which the stored energy and toroidal beta both doubled. The maximum, achieved toroidal beta was 2.5% while the ideal beta-limit for these discharges was 3.5%. The recycling light level was high compared to the baseline ohmic H-mode level and the fluctuations in the recycling light level were correlated with core MHD. The energy confinement time was high, $H_{IPB98(y,2)}$ ≈1.7, and was limited by core MHD. Measurements of ion temperature profiles and rotation velocity showed that the mid-radius ion temperature increased from 500eV to 1keV while the plasma rotation increased also from 5kms^{-1} to 50kms^{-1}. An overview of these experiments will be presented.

[1]this work partially supported by the Fonds National Suisse de la Recherche Scientifique.

NP8.00099 Physics insight from plasma shaping experiments in the TCV tokamak , A. POCHELON, EPFL CRPP, Assoc Euratom-Confederation Suisse, Lausanne, Switzerland, A. BORTOLON, Y. CAMENEN, B.P. DUVAL, A. MARINONI, H. REIMERDES, A. SCARABOSIO, TCV TEAM — The characterization of the effects of shaping on tokamak plasmas is crucial for the design of future devices, as it influences both transport and MHD stability. This is studied in TCV over a broad range of elongations k ≤2.8, positive and negative triangularities d, limited/diverted configurations, with 4.5MW EC heating. We discovered a strong dependence of electron energy diffusivity on d. The confinement time doubles as d goes from +0.4 to -0.4 in L-mode. These studies allowed the separation of the effects of shape and collisionality on transport. Trapped Electron Modes turbulence (TEM) is expected to dominate in these conditions and gyrokinetic simulations confirm the strong dependence of anomalous diffusivity on d. The change of turbulence nature (TEM/ITG) in density ramps may play a role in the abrupt intrinsic toroidal rotation inversion found in TCV as the density is ramped in high current discharges with d >0. Shape also modifies MHD and disruptions. High k is destabilizing (freq. sawteeth), high $\pm d$ is stabilizing, in agreement with MHD stability. Plasma shaping is effective in stabilizing modes and preventing disruptions, e.g. in the current ramp-up, important for the ITER high-current scenario.

NP8.00100 Effect of radio-frequency power injection on impurity profile in JET plasmas , L. CARRARO, Consorzio RFX-Padua, C. ANGIONI, IPP-Garching, C. GIROUD, UKAEA Abingdon UK, M.E. PUIATTI, M. VALISA, Consorzio RFX-Padua, P. BURATTI, ENEA Frascati, R. BUTTERY, UKAEA Abingdon UK, I. COFFEY, Queen's University Belfast, L. GARZOTTI, UKAEA Abingdon UK, D. VAN EESTER, LPP-ERM/KMS Brussels, L. LAURO TARONI, Consorzio RFX-Padua, K. LAWSON, UKAEA Abingdon UK, E. LERCHE, LPP-ERM/KMS Brussels, P. MANTICA, IFP Milano, M. MATTIOLI, Consorzio RFX-Padua, V. NAULIN, Risoe NL Denmark, JET-EFDA TEAM[1] — To maximize the reactivity of a fusion plasma the impurity content should be as low as possible in the plasma centre. RF power has been seen to flatten the impurity density profiles in various experiments, especially when applied to electrons and deposited in the centre. To evaluate the potentiality of such phenomenon as a means towards an active control of the impurity profiles, JET H-Mode and Hybrid discharges at ITER relevant collisionality (νeff<0.2), with and without RF power applied to electrons, have been transiently doped with traces of Ne, Ar, Ni and Mo. With RF the pinch parameter (ratio of convection velocity to diffusion) of all the injected impurities reduces remarkably or even reverses its sign and the impurity profiles are flattened or become hollow. Such beneficial effect is to be weighted by the increase of the metal content in the plasma that can result from the RF application. Quasi linear gyro-kinetic simulations (GS2) do not explain the observed outward pinch and refer the analysis to a full non linear approach.

[1]See the Appendix of M.L.Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006)

NP8.00101 Radiative type-III ELMy H-mode at JET: expansion of operational domain , JUERGEN RAPP, Forschungszentrum Juelich, 52425 Juelich, Germany, JET-EFDA CONTRIBUTORS TEAM — The radiative type-III ELMy H-mode seems a possible solution for an integrated ITER scenario, combining the constraints of power exhaust with acceptable confinement for an inductive ITER scenario at 17 MA / 5.3 T (q_{95} ~2.6) with a power amplification factor of Q=10. At JET this scenario has been demonstrated at 2.5 MA / 2.0T with almost all parameters within the ITER target values. However, the confinement meets marginally the ITER requirements and the fuel dilution could be improved. New experiments were performed at higher plasma current, up to 3.0 MA. At lower densities, N^{GW}=0.85, the confinement was slightly improved from $H_{98(y,2)}$ ~ 0.73 to 0.83. The Z_{eff} was reduced to values of 1.5 mainly due to the increased absolute density. The collisionality was reduced by a factor of 3. The new data show that there is no apparent dependence of the confinement on the collisionality. A review of the old large database of impurity seeded type-III ELMy H-modes together with the new results has been performed and a new analysis of the global confinement scaling with dimensionless variables is made.

NP8.00102 Damping Rate Measurements of Medium n Alfvén Eigenmodes in JET[1] , ALEXANDER KLEIN, MIT, DUCCIO TESTA, CRPP, Association EURATOM-EPFL, JOSEPH SNIPES, MIT, AMBROGIO FASOLI, CRPP, Association EURATOM-EPFL, HERVÉ CARFANTAN, Laboratoire Astrophysique de Toulouse , JET-EFDA CONTRIBUTORS TEAM — Alfvén Eigenmodes (AE's) with mode numbers 5 < n < 20 are expected to be unstable in burning tokamaks and may lead to loss of fast particle confinement. The active MHD spectroscopy program at JET has already provided a wealth of information about low n (n ≤ 2) AE's in the past decade, but a recently installed array of four antennas is capable of driving higher mode numbered (n < 100, 30 < f < 350 kHz) perturbations. In the latest JET campaign, the damping rates for several types of AE's were measured parasitically in a wide range of tokamak scenarios. We review the active MHD diagnostic and present the first measurements of medium-n AE stability on JET, then describe future plans for the active MHD spectroscopy project. The data analysis involves a novel method for resolving multiple AE's that exist at identical frequencies, which uses techniques based on the SparSpec code.

[1]This work is supported by US DOE Grant DEFG02-99ER54563.

NP8.00103 Radial correlation reflectometry measurements on the JET tokamak , A. FONSECA, B. ALPER, R. BUDNY, L. CUPIDO, J. FESSEY, A. FIGUEIREDO, S. HACQUIN, M.E. MANSO, E. MAZZUCATO, L. MENESES, A. SIRINELLI, M. WALSH, JET EFDA CONTRIBUTORS TEAM — Fluctuations and turbulence are believed to play an important role in anomalous transport of heat and particles in magnetic fusion devices. It is of vital importance to characterize transport mechanism in order to understand and control it. In correlation reflectometry (CR), two microwave beams with different frequencies are launched into the plasma from which the turbulence correlation length, L_r, and the density fluctuation level, $\tilde{n}/_n$ can be deduced; quantities that are important for the study of plasma turbulence and transport. In this paper, some results of L_r obtained with the four X-mode CR systems installed at Joint European Torus (JET) are reported. Experimentally, it was observed that L_r increases from the plasma edge to the plasma core. Also, L_r decreases inside the Internal Transport Barriers (ITB) [1]. The results obtained at JET agree quiet well with the L_r dependence measured in other tokamak machines. [1] - A.C.A. Figueiredo, et.al., *in the 34th EPS Conference on Plasma Physics, Warsaw, Poland, 2-7 July, (2007).*

NP8.00104 Factors that Influence RF Breakdown in Antenna Systems , J.B.O. CAUGHMAN, F.W. BAITY, D.A. RASMUSSEN, Oak Ridge National Laboratory, M. AGHAZARIAN, C.H. CASTANO GIRALDO, DAVID RUZIC, University of Illinois at Urbana-Champaign, OAK RIDE NATIONAL LABORATORY TEAM, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM — One of the main power-limiting factors in antenna systems is the maximum voltage that the antenna or vacuum transmission line can sustain before breaking down. The factors that influence RF breakdown are being studied in a resonant 1/4-wavelength section of vacuum transmission line terminated with an open circuit electrode structure. Breakdown can be initiated via electron emission by high electric fields and by plasma formation in the structure, depending on the gas pressure. Recent experiments have shown that a 1 kG magnetic field can influence plasma formation at pressures as low as 8x10-5 Torr at moderate voltage levels (<5 kV). Ultraviolet light, with energies near the work function of the electrode material, can induce a multipactor discharge and limit power transmission. Details of these experimental results, including the effect of electrode materials (Ni and Cu), will be presented. Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725. Work supported by USDOE with grant DE-FG02-04ER54765

NP8.00105 ITER AND MAGNETIC FUSION DEVELOPMENT —

NP8.00106 ITER Low-Field-Side-Reflectometer Design Considerations[1] , W.A. PEEBLES, P-A. GOURDAIN, T.L. RHODES, L. ZENG, S. KUBOTA, G. WANG, E.J. DOYLE, UCLA — The ITER environment will be extremely harsh with heat loads and neutron flux levels reaching unprecedented levels. Ensuring the availability, reliability and accuracy of profile monitoring capabilities in ITER represents a major challenge. In contrast to optical-based diagnostics millimeter-wave systems are well-suited to this harsh environment. The first detailed U.S. assessment of the low-field-side reflectometer system is presented. Relativistic effects occur at high temperatures introducing a number of measurement challenges. Large changes in the reflectometry cutoff location occur due to relativistic mass correction, which leads to density profile measurement in ITER becoming dependent on knowledge of the local electron temperature. Furthermore, cutoff contours can become hollow and electron cyclotron absorption increases. These effects restrict core access and significantly modify wave propagation in the core plasma. The impact of these issues on reflectometry measurement capabilities is described and potential solutions discussed.

[1]U.S. Department of Energy, PPPL/USIPO Subcontract #S006786-F.

NP8.00107 Study of Doppler Backscattering for Plasma Rotation Measurements on ITER[1] , T.L. RHODES, S. KUBOTA, W.A. PEEBLES, L. SCHMITZ, L. ZENG, E.J. DOYLE, G. WANG, University of California-Los Angeles — Millimeter-wave based diagnostic systems are well suited to the harsh environment expected in ITER and other future burning plasmas. One such technique, Doppler reflectometry, has been proposed for plasma rotation measurements on ITER. In this technique radiation is injected at an angle with respect to the plasma edge and the Doppler shift of the density fluctuations monitored. This shift depends upon both the background ExB velocity as well as the intrinsic propagation velocity of the fluctuations. The physics of Doppler backscattering and its specific application to ITER are studied using full wave 2D simulations for ITER scenarios. Near the cutoff layer a long wavelength electric field pattern is formed roughly parallel to the flux surface. It is this field pattern that interacts strongly with the density fluctuations propagating in the poloidal direction, i.e. within the flux surface. Data from the DIII-D tokamak as well as the limitations and potential of this method for ITER will be presented and discussed.

[1]Supported by the US DOE under PPPL/USIPO Subcontract S006786-F.

NP8.00108 Initial design of visible/IR camera optics for upper ports of ITER[1] , C.J. LASNIER, L.G. SEPPALA, K. MORRIS, M.E. FENSTERMACHER, M. GROTH, LAWRENCE LIVERMORE NATIONAL LABORATORY TEAM — We show an initial optical design for the visible/IR camera systems that are a US responsibility for 6 of the ITER upper ports. Optics are enclosed in a tube with a entrance aperture through the blanket shield module. An aspheric collection mirror sends light to a flat mirror that redirects the beam along the port tube. Dogleg mirrors provide a jog in the beam, allowing for neutron shielding. The beam is spatially split into visible and IR beams inside the port flange, for separate vacuum windows. Spatial resolution is diffraction-limited by the aperture, which in turn depends on the size of the optics allowed in the port plug. For a view of the entire outer divertor plate with no intermediate focusing optics in the port tube, the spatial resolution is poorer than the specified 3mm. We show the resolution advantages of reducing the field of view and of adding a lens in the port plug.

[1]Work performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. Work supported by the US ITER Project Office.

NP8.00109 System Design of the MSE Diagnostic for ITER[1] , M.A. MAKOWSKI, S.L. ALLEN, M. GU, C.T. HOLCOMB, S. LERNER, K. MORRIS, N. WONG, Lawrence Livermore National Laboratory, R. CHIPMAN, University of Arizona — System designs for both the core and edge motional Stark effect (MSE) diagnostics for ITER have been developed and continue to be refined. An integrated system model has been developed that includes the emission physics and full optical properties of the four mirror relay system. Emphasis has been placed on minimizing the polarization aberrations of the optical relay system. A mechanical design has also been developed that can be coupled to a neutronics code for rapid evaluation of the shielding efficacy as alternative designs are examined. As part of the design program, candidate mirror materials are being characterized and then incorporated into the optics model to evaluate their impact on system performance. An overview of the system will be presented, together with various aspects of the emission model and optical and mechanical designs.

[1]Supported by the US DOE under W-7405-ENG-48.

NP8.00110 Evaluation of a DNB for ITER-Based on Common Long-Pulse Positive Ion Source Technology[1] , D.M. THOMAS, R.W. CALLIS, R.M. HONG, H.K. CHIU, General Atomics, M. VON HELLERMANN, FOM Inst. for Plasma Physics — The use of a diagnostic neutral beam (DNB) is critical for the ITER diagnostic mission in order to provide radially resolved profiles of helium ash density as well as ion temperature, density, and rotation profiles. However, the estimated performance requirements for a suitable beam have yet to be demonstrated for either negative or positive ion source technology. In this paper we re-examine the suitability of existing common long pulse source (CLPS) technology, as exemplified in the DIII-D and TFTR programs, to provide a positive-ion-based DNB that will satisfy the ITER mission requirements with high reliability and ease of modulation. Straightforward modifications of the existing ion sources are expected to provide greater than 50 A of full energy hydrogen atoms at 100 keV, with a peak current density at the shield aperture approaching 200 A/m^2. Estimated S/N for BES and CXRS measurements for specific ITER operating scenarios will also be presented.

[1]Supported by the US DOE under DE-FC02-04ER54698.

NP8.00111 Notch Filter Possibilities for ITER Stray Gyrotron Radiation[1] , PAUL WOSKOV, MIT PSFC — ITER will have multi megawatt gyrotron systems at 170, 120, and potentially at 60 GHz for ECH, current drive, NTM control, start up, and CTS diagnostics. The ITER environment will therefore have significant background levels of stay radiation at these frequencies that can pose a problem to a number of diagnostic systems. Several, narrowband reject filter approaches have been examined. These include fundamental mode waveguide (wg) filters, quasi-optical interference filters, and molecular absorption gases. Fundamental wg stop band filters are available for 60 and 120 GHz, but have limited pass bands and may not be readily extended to 170 GHz. An overmoded corrugated wg interference filter with $>$ 30 db rejection over a 40 MHz band, a free spectral range of 6.7 GHz, and minimum insertion loss of 0.6 dB has been tested over the 100-145 GHz range and could be used to over 170 GHz. The OCS molecule as a series of 12 GHz spaced rotational lines with peaks at 60.8, 121.6, and 170.3 GHz with absorptions of 0.4, 3.2, 8.0 dB/m, respectively that could be used at low pressure with slight gyrotron adjustment. The H_2S molecule has absorption at 168.8 GHz that at atmospheric pressure would rejection by 8.6 dB/m at 170 GHz with insertion loss $<$ 0.01 dB/m below 156 GHz. The relative merits of these notch filter approaches will be presented.

[1]supported by U. S. DOE

NP8.00112 ITER Ion Cyclotron Transmission Line and Tuning System Design Options and Choices , D.W. SWAIN, R.H. GOULDING, D.A. RASMUSSEN, Oak Ridge National Laboratory — The ITER ion cyclotron system is required to deliver 20 MW of power to the plasma for ion heating and for current drive over the 40- to 55-MHz frequency range. An externally tuned antenna module consisting of an array of 24 (4 toroidal x 6 poloidal) current straps is mounted in an equatorial port. The straps are connected (internal to the antenna) in upper and lower poloidal triplets. Eight rf sources are connected to the transmission line and tuning/decoupling system and then to the feeds for the triplets. Two external tuning options that will permit ICH operation with ELMy H-modes are under consideration. In one option, conjugate-T, plasma load resilient, circuits are connected to triplet pairs. The conjugate-T matching components are external to but near the antenna. An alternate design uses a series of combiner-splitters (ELM dumps) to protect the rf sources from reflected power from transient plasma load variations. This talk will describe the design options, evolution of the different designs, and the pros and cons of the options. Future design work and R&D will be needed and will be described. Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

NP8.00113 Effects of local ECCD driven by the optimized Equatorial and Upper EC Launchers on ITER[1] , C. ZUCCA, O. SAUTER, M.A. HENDERSON, CRPP-EPFL, Association EURATOM-Confédération Suisse, Lausanne, Switzerland, D. FARINA, G. RAMPONI, Istituto di Fisica del Plasma, EURATOM-ENEA-CNR Association, Milan, Italy — The present ITER base-line design has the EC launchers providing only co-ECCD. A variant of the EC system was recently proposed to enlarge the physics programs covered by the Upper (UL) and Equatorial (EL) Launchers. This study aims to provide the potential range of the q profile control achievable by this optimization, including the possibility to drive cnt-ECCD and central ECH. Since the EL can only drive co-ECCD, if ECH power is needed to assist the L-H transition during ramp-up, it can have detrimental effects on the final profiles, such as removing the reverse shear. Cnt-ECCD offers greater control of the plasma current density and provides, when balanced with co-ECCD, pure ECH with no net driven current. The performance of the EL in tailoring the q profile by adding co-/cnt-ECCD is analyzed. Effects of current drive and deposition width on sawtooth control by UL are also discussed. The modeling is carried out with both equilibrium and transport codes.

[1]This work is supported in part by the Swiss National Science Foundation.

NP8.00114 170 GHz ITER ECH Transmission Line Estimated Losses and Testing , M.A. SHAPIRO, S.T. HAN, J.R. SIRIGIRI, D. TAX, R.J. TEMKIN, P.P. WOSKOV, MIT PSFC, T.S. BIGELOW, D.A. RASMUSSEN, ORNL — The US will build 24 Transmission Lines (TL) connecting the 170 GHz gyrotrons to the ITER tokamak. Losses in the 63.5 mm diameter corrugated waveguide are estimated using an approximate analytical theory as 11% for a TL length of about 100 m. Experimental demonstration of such low loss transmission is a challenge. The results of estimation can be verified through precise measurements and advanced simulations. A set of 170 GHz corrugated waveguide TL components built by General Atomics is under test at MIT. High precision measurement techniques include a vector network analyzer and a radiometer. The miter bends are tested as critical TL components, since they are responsible for the largest amount of mode conversion and loss. The testing results are compared with advanced simulations using the HFSS code (Ansoft Corp.). Another critical issue is additional loss due to thermal or mechanical distortion of the miter bend mirror and the waveguide sections during 1 MW CW power transmission. The critical issues have been revealed in high power CW test of the 170 GHz TL using the 1 MW 170 GHz gyrotron at JAEA, Japan. The US is planning a high power test stand for testing the ITER TL. Advanced thermo-mechanical simulations and HFSS electromagnetic simulations will be conducted to explain the experimental results.

NP8.00115 Digital Holography Density Diagnostic for ITER Disruption Mitigation Test Stand[1]

, C.E. THOMAS JR., Third Dimension Technologies, L.R. BAYLOR, S.K. COMBS, Oak Ridge National Laboratory — Digital Holography holds the promise of providing very fast high-resolution density data at a relatively inexpensive price. A proof-of-principle system to demonstrate feasibility of the diagnostic is being designed and built on the ITER Disruption Mitigation Test Stand at ORNL. Although holographic interferometry has long been used as a density diagnostic, this will be the first application of digital holography to this task. While risky due to its unproven nature, digital holography offers the opportunity to provide an unprecedented fine-grain measurement of gas and/or plasma density. In a crossed-sightline configuration, 3-D density diagnosis is possible. This opens the door to developing new physics understanding both for disruption mitigation technology and on experimental fusion research devices. Understanding usually leads to both control and improvement. Details of the diagnostic system design and expected performance will be presented.

[1]Acknowledgement–This work is partially supported by the USDOE under Grant DE-FG02-07ER84724. The support of the Department of Energy is gratefully acknowledged.

NP8.00116 Beryllium deposition on ITER first mirrors: layer morphology and influence on reflectivity[1]

, GREGORY DE TEMMERMAN, MATT BALDWIN, RUSS DOERNER, DAISUKE NISHIJIMA, RAY SERAYDARIAN, UCSD, La Jolla, KLAUS SCHMID, CHRISTIAN LINSMEIER, LAURENT MAROT, University of Basel, Switzerland — Metallic mirrors will be essential components of the ITER optical diagnostics whose reliability may be affected by mirror reflectivity changes due to erosion and/or deposition of impurities (C, Be). The present study aims to assess the effect of Be deposition on the reflectivity of Cu and Mo mirrors and to collect data on the morphology of these layers. Mirrors were exposed in PISCES-B to collect eroded material from graphite and beryllium targets exposed to a Be-seeded D_2 plasma. After exposure, relative reflectivity of the mirrors was measured and the deposited layers were studied using different surface analysis techniques. Be layers formed in PISCES-B exhibit high levels of porosity and a reflectivity much lower than that of pure Be. It is found that if Be deposition occurs on ITER first mirrors, the reflectivity of the coated mirrors will strongly depend on the layer morphology, which in turn depends on the deposition conditions.

[1]DOE Contract #DE-FG02-07ER54912.

NP8.00117 Codeposition of deuterium with the ITER mix of materials[1]

, RUSS DOERNER, MATT BALDWIN, GREGORY DE TEMMERMAN, DAISUKE NISHIJIMA, Center For Energy Research, CH LINSMEIER, JOCHIM ROTH, KLAUS SCHMID, Max Planck Institut fur Plasmaphysik, Garching — Tritium accumulation within the ITER vacuum vessel is expected to be dominated by codeposition. Since ITER will employ a unique combination of plasma-facing materials (Be, C and W), the codeposition properties of each of the materials, and combinations of the materials, must be evaluated. The database on codeposition is reviewed and new measurements from PISCES-B are used to understand apparent discrepancies found in the literature. The variables determining the deuterium content in the layers appear to be the surface temperature during the codeposition, the morphology of the layer and the energy of particles incident on the codepositing layers. In addition to retention in codeposited layers, the ease of removal of deuterium from codeposits will determine their importance for ITER. The release of deuterium during vacuum annealing will be compared for each of the three proposed ITER materials, as well as from mixtures of the materials.

[1]Supported By US-EU Collaboration on Mixed Materials, DOE Grant #DE-FG02-07ER54912.

NP8.00118 Carbon Atom and Cluster Sputtering Yields under Low Energy Noble Gas Bombardment

, EIDER OYARZABAL, RUSS DOERNER, MASASHI SHIMADA, GEORGE TYNAN, UCSD — Carbon atom and cluster (C_2 and C_3) sputtering yields are measured during different noble gas (Xe, Kr, Ar, Ne and He) bombardment from a plasma, for low incident energies (75 -225 eV). A quadrupole mass spectrometer (QMS) is used to detect the fraction of sputtered neutrals that is ionized in the plasma and to obtain the angular distribution by changing the angle between the target and the QMS aperture. A one dimensional Monte Carlo code is used to simulate the plasma and the sputtered particles from the sample to the QMS, and to obtain the elastic scattering crossections of C, C_2 and C_3 with the different bombarding gas neutrals by changing the distance between the sample and the QMS and fitting the simulation results to the experimental results. The total sputtering yield ($C+C_2+C_3$) for each bombarding gas is obtained from weight loss measurements and the sputtering yield for C, C_2 and C_3 is then calculated from the integration of the measured angular distribution, taking into account the scattering and ionization of the sputtered particles from the sample to the QMS. We observe a clear decrease of the cluster (C_2 and C_3) to atom sputtering ratio as the incident ion mass decreases.

NP8.00119 A Fitting Routine to Obtain Temperature and Relative Spectral Emissivity from Mixed Material (C, W, Be) Surfaces in PSI Experiments[1]

, RAY SERAYDARIAN, JEREMY HANNA, RUSS DOERNER, MATT BALDWIN, Center For Energy Research — A nonlinear least-squares fitting code has been written to fit a black body profile multiplied by a polynomial spectral emissivity to the data from an IR spectroscopy diagnostic on the PISCES-B machine. The result is the absolute surface temperature and the coefficients of the polynomial emissivity. Emissivity measurements are important for thermal balance calculations of first wall materials in ITER, especially under conditions for which mixed materials can be created (e.g., combinations of C, W and Be) for which no other emissivity data are available. A straightforward data-to-theory-function fit is made possible by an intensity calibration using a commercially available illumination source. The raw spectrum has sufficient detail (512 pixels) to see and eliminate atomic line emission and absorption features from the spectrum before fitting. Fitting code details and preliminary experimental data analysis will be presented and discussed.

[1]DOE Contract #DE-FG02-07ER54912.

NP8.00120 Compact Stellarator Path to DEMO[1]

, J.F. LYON, Oak Ridge National Laboratory, U.S. STELLARATOR COMMUNITY COLLABORATION — Issues for a DEMO reactor are sustaining an ignited/high-Q plasma in steady state, avoiding disruptions and large variations in power flux to the wall, adequate confinement of thermal plasma and alpha-particles, control of a burning plasma, particle and power handling, etc. Compact stellarators have key advantages – steady-state high-plasma-density operation without external current drive or disruptions, stability without a close conducting wall or active feedback systems, and low recirculating power – in addition to moderate plasma aspect ratio, good confinement, and high-beta potential. The ARIES-CS study established that compact stellarators can be competitive with tokamaks as reactors. Many of the issues for a compact stellarator DEMO can be answered using results from large tokamaks, ITER D-T experiments and fusion materials, technology and component development programs, in addition to stellarators in operation, under construction or in development. However, a large next-generation stellarator will be needed to address some physics issues: size scaling and confinement at higher parameters, burning plasma issues, and operation with a strongly radiative divertor. Technology issues include simpler coils, structure, and divertor fabrication, and better cost information.

[1]Support: DOE Contract DE-AC05-00OR22725 with UT-Battelle LLC.

NP8.00121 Establishing Physical and Engineering Science Base to Bridge from ITER to Demo , Y.-K. MARTIN PENG, ORNL. UT-Battelle, M. ABDOU, UCLA, D. GATES, PPPL, C. HEGNA, U Wisconsin, D. HILL, LLNL, F. NAJMABADI, UCSD, G. NAVRATIL, R. PARKER, MIT, NCT DISCUSSION GROUP COLLABORATION — A Nuclear Component Testing (NCT) Discussion Group emerged recently to clarify how "**a lowered-risk, reduced-cost approach can provide a progressive fusion environment beyond the ITER level to explore, discover, and help establish the remaining, critically needed physical and engineering sciences knowledge base for Demo.**" The group, assuming success of ITER and other contemporary projects, identified critical "gap-filling" investigations: plasma startup, tritium self-sufficiency, plasma facing surface performance and maintainability, first wall/blanket/divertor materials defect control and lifetime management, and remote handling. Only standard or spherical tokamak plasma conditions below the advanced regime are assumed to lower the anticipated physics risk to continuous operation (∼2 weeks). Modular designs and remote handling capabilities are included to mitigate the risk of component failure and ease replacement. Aspect ratio should be varied to lower the cost, accounting for the contending physics risks and the near-term R&D. Cost and time-effective staging from H-H, D-D, to D-T will also be considered. *Work supported by USDOE.

NP8.00122 Crossing the Next Frontier[1] , R. GOLDSTON, J. MENARD, PPPL, J. BROOKS, ANL, R. DOERNER, UCSD, D. GATES, G.-Y. FU, N. GORELENKOV, R. KAITA, S. KAYE, G. KRAMER, H. KUGEL, R. MAJESKI, M. ONO, C. SKINNER, J. STRACHAN, PPPL, J. HARRIS, R. MAINGI, ORNL, M. KOTSCHENREUTHER, S. MAHAJAN, P. VALANJU, U Texas, R. NYGREN, M. ULRICKSON, SNL, D. RUZIC, U Ill, S. SABBAGH, Columbia, V. SOUKHANOVSKII, LLNL — The plasma-material interface is the next frontier in fusion science. ITER's approaches to heat flux and tritium retention do not extrapolate to Demo. Defining questions at this frontier include: Can extremely high radiated-power fraction be consistent with high confinement and low Z_{eff}? Can magnetic flux expansion or edge ergodization reduce heat loads sufficiently? Can tungsten survive with acceptable core radiation and tritium retention? Can liquid metals more effectively handle high heat flux, off-normal loads and tritium exhaust? Answers must be integrated with high-performance, fully steady state plasma operation, avoiding ELMs and eliminating disruptions. The vehicle to cross this frontier is a high-power-density plasma with long pulses, excellent diagnostic access, flexible first wall, divertor, heating, current drive and plasma control systems, extensive deuterium and trace tritium operation, and the ability to test a range of plasma-facing materials at reactor-relevant temperature.

[1]This work supported in part by U.S. DOE Contract # DE-AC02-76CH03073.

NP8.00123 Fusion Development Facility – Mission and Overview[1] , R.D. STAMBAUGH, V.S. CHAN, C.P.C. WONG, GA — A Fusion Development Facility (FDF) is proposed to make possible a fusion demonstration power plant (DEMO) as the next step after ITER. To make possible a DEMO of the ARIES-AT type, the mission of the FDF should be to carry forward Advanced Tokamak physics and enable development of fusion energy applications. FDF should demonstrate advanced physics operation of a tokamak in steady-state with burn, producing 100-250 MW fusion power with modest energy gain (Q<5) in a modest sized device. Full noninductive, high bootstrap operation will enable continuous operation for periods up to two weeks. FDF must further develop all elements of AT physics for an advanced performance DEMO. With neutron flux at the outboard midplane of 1-2 MW/m^2 and a goal of a duty factor of 0.3, FDF can produce fluences of 3-6 MW-yr/m^2 in ten years of operation. FDF will have a goal of producing its own tritium and building a supply to start up DEMO. The development of blankets suitable for tritium, electricity, and hydrogen production will be done in port modules. FDF, ITER, IFMIF, and other AT devices will provide the basis for a fusion DEMO power plant of the ARIES-AT type.

[1]Supported by the GA IR&D funding.

NP8.00124 Physics-Based Performance Projections for Fusion Development Facility[1] , V.S. CHAN, R.D. STAMBAUGH, M.S. CHU, R.K. FISHER, C.M. GREENFIELD, D.A. HUMPHREYS, L.L. LAO, J.A. LEUER, T.W. PETRIE, R. PRATER, G.M. STAEBLER, H.E. ST JOHN, P.B. SNYDER, A.D. TURNBULL, M.A. VAN ZEELAND, General Atomics — The Fusion Development Facility (FDF) is a fusion application development facility based on advanced tokamak physics with copper magnets and tritium breeding capability. Theory based stability and transport studies are used to validate the performance projections from a system study based on simplified models. Ideal global and edge stability limits established by further optimization of high performance equilibria obtained in existing experiments indicate that the FDF power density and neutron flux requirements can be met with strong shaping and feedback control. Transport analysis using physics-based transport model with an edge condition consistent with the pedestal stability limit indicate the FDF confinement requirement can also be achieved. Interesting opportunities for study of alpha physics and challenges on first walls will be discussed.

[1]Supported by the GA IR&D funding.

NP8.00125 Numerical Study of Equilibrium, Stability, and Advanced Resistive Wall Mode Feedback Algorithms on KSTAR[1] , OKSANA KATSURO-HOPKINS, S.A. SABBAGH, J.M. BIALEK, Columbia University, H.K. PARK, PPPL, J.Y. KIM, K.-I. YOU, KBSI, A.H. GLASSER, LANL, L.L. LAO, General Atomics — Stability to ideal MHD kink/ballooning modes and the resistive wall mode (RWM) is investigated for the KSTAR tokamak. Free-boundary equilibria that comply with magnetic field coil current constraints are computed for monotonic and reversed shear safety factor profiles and H-mode tokamak pressure profiles. Advanced tokamak operation at moderate to low plasma internal inductance shows that a factor of two improvement in the plasma beta limit over the no-wall beta limit is possible for toroidal mode number of unity. The KSTAR conducting structure, passive stabilizers, and in-vessel control coils are modeled by the VALEN-3D code and the active RWM stabilization performance of the device is evaluated using both standard and advanced feedback algorithms. Steady-state power and voltage requirements for the system are estimated based on the expected noise on the RWM sensor signals. Using NSTX experimental RWM sensors noise data as input, a reduced VALEN state-space LQG controller is designed to realistically assess KSTAR stabilization system performance.

[1]Work supported by U.S. DOE Grant DE-FG02-99ER54524.

NP8.00126 KSTAR Equilibrium Reconstruction with EFIT Code[1] , KWANG-IL YOU, D.K. LEE, S.H. HAHN, National Fusion Research Center, L.L. LAO, General Atomics, KSTAR TEAM — For application to the KSTAR (Korea Superconducting Tokamak Advanced Research) device, we have made some modification to the EFIT code and installed it on our computing system. The main function of EFIT is reconstruction of plasma equilibrium using discharge data. After every discharge, the code will be automatically run for a chosen time array and the results will be stored in the same way as experimental data will be. An MDSplus system will be used as the data storage for KSTAR; therefore, the EFIT reads experimental data from the MDSplus server and writes the results to it. We have added some subroutines to EFIT for direct link with the MDSplus server and also converted EFIT to Fortran 95 form. Test runs of the code will be made by using plasma simulator in the KSTAR plasma control system. This paper will also present some results of equilibrium data obtained with the equilibrium mode of EFIT.

[1]Work supported by Korean Ministry of Science and Technology under KSTAR Project Contact

NP8.00127 Criteria for Neoclassical Tearing Modes Suppression in KSTAR , Y.S. PARK, Y.S. HWANG, Seoul National University — In KSTAR, neoclassical tearing modes(NTMs) will be suppressed by using 170GHz electron cyclotron current drive(ECCD) system with steering mirrors that align the current deposition to NTM locations. As an initial stage of NTM suppression study, 1 MW ECCD power will be used to suppress m/n = 3/2 and 2/1 NTMs. To confirm the feasibility of successful suppression of the modes under the proposed KSTAR environment, modified Rutherford equation(MRE) which encapsulates stability of NTMs is constructed for the target equilibrium of KSTAR. The geometric coefficients in MRE are obtained by comparing saturated sizes of NTMs from ISLAND code [1] with the amounts of local bootstrap currents from ONETWO. Parameters related to the operation of ECCD are analyzed by TORAY-GA linear ray-tracing code. Due to the small ECCD power available at the initial stage of KSTAR, condition of the optimum ECCD modulation is considered in the analysis to maximize suppression performance. From the analyses, criteria such as the minimum ECCD power required for complete suppression of the modes and the optimum conditions of EC wave launch angle and modulation duty factor are derived for the successful NTM suppression in KSTAR. [1] C.N. Nguyen, G. Bateman and A.H. Kritz, Phys. Plasmas 11 3460 (2004)

NP8.00128 Two-Dimensional Simulation of Edge Localized Modes in the Edge-SOL Region of the KSTAR Tokamak[1] , KI MIN KIM, HYUN-SUN HAN, SANG HEE HONG, Seoul National University — H-mode plasmas in the tokamak are frequently perturbed by oscillating instabilities known as ELMs (Edge Localized Modes) in the edge-SOL (Scrape-Off Layer) region. Large losses of plasma particle and energy by ELMs have a critical influence on the degradation of plasma confinement, and the released energies can cause serious damages to the plasma facing components in the edge region. In order to investigate the effects of ELMs on the tokamak operation, a two-dimensional predictive simulation has been carried out for the KSTAR (Korea Superconducting Tokamak Advanced Research) tokamak by the B2 transport code. Double-null edge-SOL geometry and reference ELMy H-mode scenarios of KSTAR are considered, and the enhanced transports during an ELM period are reproduced with the modified transport coefficients at the edge. The duration and frequency of ELMs are varied to simulate type-I and type-III ELMs. Simulation results show the dynamics of the plasma properties focused on the heat fluxes on the divertor target during ELMs. In addition, parametric characteristics of the divertor heat load distributions are discussed.

[1]This work has been supported by National Fusion Research Center in Korea.

NP8.00129 SOL-Divertor Plasma Simulation in the KSTAR Tokamak with a Neutral Transport Model Using the TEP method , HYUN-SUN HAN, KI MIN KIM, SANG HEE HONG, Seoul National University — A two-dimensional numerical simulation has been carried out to analyze the transport phenomena of plasma and neutrals in Scrape- off Layer (SOL) and divertor region of the Korea Superconducting Tokamak Advanced Research (KSTAR) tokamak. In this numerical work, the transmission and escape probability (TEP) method is used for a neutral transport model by adapting the GTNEUT [1] code, which is coupled with a plasma transport model based on the Braginskii's fluid formulation. Prior to combining the GTNEUT code with the plasma transport one, preliminary tests are conducted by comparison with a Monte Carlo method to check the numerical accuracy and efficiency of the neutral model. A performance improvement of computing time is achieved during the coupling processes by pre-computing the various transmission coefficients and setting up an interpolation lookup table. As results of the simulation, plasma density and temperature distributions in the SOL-divertor region are calculated for the baseline operation of the KSTAR tokamak. This integrated modeling method could be extended to the simulation of more complicated edge transport for the advanced tokamak operation including impurity transport.
[1] J. Mandrekas, Comput. Phys. Comm., 161, 36 (2004)

NP8.00130 ECEI/MIR Optical Designs for KSTAR[1] , Z. SHEN, T. LIANG, X. KONG, C.W. DOMIER, N.C. LUHMANN, JR., University of California at Davis, H.K. PARK, Princeton Plasma Physics Laboratory — 2-D plasma imaging diagnostic system is being developed for the KSTAR tokamak to image electron temperature profiles and fluctuations via Electron Cyclotron Emission Imaging (ECEI) and electron density fluctuations via Microwave Imaging Reflectometry (MIR). Optical designs have been developed for both low field (1.5-2.0 T) and high field (3.0-3.5 T) operation scenarios. Each ECEI system consists of a pair of 24 element mixer arrays producing 768 (24×32) channel temperature fluctuation images. Each MIR system consists of a single 16 element mixer array producing 128 (16×8) channel density fluctuation images. Use of in-vessel reflective optics permits both systems to view the KSTAR plasma through a relatively small vacuum window. System details, including preliminary optical and electronics designs for low and high field configurations, will be presented.

[1]Work supported by U.S. DoE Grant DE-FG02-99ER54531.

NP8.00131 Experimental investigation of the novel x-ray tube for the KSTAR x-ray image crystal spectrometer[1] , JUN-GYO BAK, SANG-GON LEE, MIN-GAP BOG, National Fusion Research Center, UK-WON NAM, Korea Astronomy & Space Science Institute, MYUNG-KOOK MOON, JONG-KYU CHEON, Korea Atomic Energy Research Institute — A novel x-ray tube with an anode and a line filament has been developed for the *in-situ* calibration of a two dimensional segmented position-sensitive, multi-wire proportional counter (2D detector) in the KSTAR x-ray image crystal spectrometer (XICS). For the investigation of the performance of the x-ray tube as a line x-ray source for the calibration of the 2D detector, the images from the x-ray tube with Cu and Al anodes are measured by using a pinhole and the 2D detector. The characteristics of the x-ray images, such as the width and length of the image, are investigated and two images from the x-ray tube using Cu and Al anodes are compared. This work will be needed for the application of the in-situ calibration of the XICS. In this work, the experimental investigation of the x-ray tube will be presented.

[1]Work supported by the Korea Research Council of Fundamental Science & Technology under contract No. C-Research-2006-08-NFRC.

NP8.00132 Commissioning activities of the initial magnetic diagnostics for KSTAR tokamak[1] , SANG GON LEE, JUN GYO BAK, EUN MIE KA, National Fusion Research Center — The initial magnetic diagnostics for the KSTAR superconducting tokamak including three Rogowski coils, five flux/voltage loops, and sixty-four magnetic field probes have been successfully installed. The Rogowski coils, flux/voltage loops, and magnetic field probes measure the total plasma current, poloidal flux and loop voltage, and local poloidal magnetic field for the plasma position control and equilibrium studies, respectively. Accurate position measurements after installation for all of these initial magnetic diagnostics and *in situ* calibration for the Rogowski coils were finished. Data acquisition systems for these initial magnetic diagnostics are currently under preparation. Detail commissioning activities before the first plasma from these initial magnetic diagnostics will be presented.

[1]Work supported by the Korea Ministry of Science and Technology under the KSTAR project contract.

NP8.00133 EAST First Diverted Plasma Operations – Plasma Control and Vertical Stabilization[1] , A.W. HYATT, J.A. LEUER, D.A. HUMPHREYS, G.L. JACKSON, R.D. JOHNSON, B.G. PENAFLOR, D.A. PIGLOWSKI, M.L. WALKER, A.S. WELANDER, GA, D. MUELLER, PPPL, B.J. XIAO, Q.P. YUAN, H.Z. WANG, P. FU, X. GONG, J. LUO, Y. WAN, J. LI, ASIPP, EAST TEAM — EAST, the first operational fully superconducting tokamak, has a poloidal field (PF) coil set that is similar to ITER. The EAST digital plasma control system (PCS), based on the DIII-D PCS, allowed EAST to rapidly progress from first plasma to diverted operations in a few months, and GA personnel to remotely support the initial rollout of the PCS. Effective combined I_p, R_p, and Z_p control with a fully independent PF coil set has been demonstrated. Careful current programming of the PF coils demonstrated stable diverted plasma operation. AC heating and breakdown concerns limited the PF coils' power supplies' bandwidth, voltage, and ability to counter the growth of n=0 instabilities when the plasma elongation kappa, $\kappa \geq 1.15$. Auxiliary internal PF coils driven by a fast power supply (3 kHz, 5 kA, 600 V), provided effective vertical stabilization at $\kappa \geq 1.8$. Examples and simulations will be shown.

[1]Supported by the US DOE under DE-FC02-04ER54698 and DE-AC02-76CH03073.

NP8.00134 Major Improvements in Diagnostic Neutral Beam Performance on HT-7 and EAST and Implications for CXRS[1] , HE HUANG, WILLIAM L. ROWAN, Fusion Research Center, The University of Texas at Austin, YUEJIANG SHI, JUN LI, DONGHAI DING, CHUNDONG HU, BAONIAN WAN, Chinese Academy of Sciences, Institute of Plasma Physics — To improve the sensitivity of the charge exchange recombination spectroscopy (CXRS) diagnostic on HT-7 and the prospects for CXRS on EAST, a magnetic filter was added to the magnetic bucket plasma source on the diagnostic neutral beam (DNB). The density of the main energy component of the beam was increased by a factor of 2, radically improving the prospects for CXRS. The effect of the magnetic filter is to isolate the plasma production region from the beam extraction region. Further improvements in operation of the plasma source will be undertaken by re-engineering gas delivery and power supplies to increase the operational regime. New proposals for more efficient plasma excitation will be discussed. Simulations with the expected improvement both for HT-7 and for EAST are used to guide CXRS optical designs for the devices.

[1]Supported by CAS,IPP, and USDOE DE-FG03-97ER54415

Wednesday, November 14, 2007 9:30AM - 12:30PM –

Session NM4 Mini-conference on Angular Momentum Transport in Laboratory and Nature III

Rosen Centre Hotel Salon 1/2

9:30AM NM4.00001 Spontaneous Rotation in Tokamak Plasmas , JOHN RICE, MIT — Spontaneous toroidal rotation has been observed in Alcator C-Mod tokamak plasmas with no external momentum input. The magnitude of the rotation ranges from –60 km/s in discharges with low energy confinement (L-mode) to +140 km/s in plasmas with good energy confinement (H-mode). The rotation in L-mode plasmas is found to depend strongly and in a complicated fashion on the electron density, the plasma current and the magnetic topology, and is typically in the counter-current direction. In contrast, the rotation velocity in H-mode discharges is observed to scale linearly with the plasma stored energy (or plasma pressure) normalized to the plasma current, a relatively simple dependence, and is directed co-current. Immediately following the abrupt transition from L-mode to H-mode, the co-current rotation appears near the plasma edge and propagates to the center on a time scale similar to the energy confinement time, but anomalously fast compared to the classical (collisional) momentum diffusion time. Very similar scalings in H-mode plasmas have been made on many tokamaks worldwide in a variety of operating conditions, indicating the fundamental nature of spontaneous rotation. A universal scaling is beginning to emerge with an eye toward prediction of the level of rotation expected in future devices such as ITER. At present there is no comprehensive theory which explains this phenomenon.

10:00AM NM4.00002 Momentum Confinement on DIII-D with Low Net Neutral Beam Torque[1] , W.M. SOLOMON, R.V. BUDNY, D. MIKKELSEN, R. NAZIKIAN, S.D. SCOTT, M.C. ZARNSTORFF, PPPL, K.H. BURRELL, J.S. DEGRASSIE, R.J. GROEBNER, J.E. KINSEY, C.C. PETTY, GA — Momentum confinement was investigated in ELMing H-mode plasmas with elevated q_{min}. Torque scans were performed at constant β_N, and the rotation profile was measured using charge exchange recombination (CER) spectroscopy. Studies of the mechanical angular momentum in the plasma show a non-uniform response to the applied neutral beam torque, resulting in a torque dependence of the momentum confinement time. Under nominally balanced neutral beam injection, the plasma maintains a significant rotation in the same direction as the plasma current (co-rotation). The intrinsic rotation can be understood as being due to an offset in the applied torque (i.e. an "anomalous torque"). Analysis including the effect of anomalous fast ion diffusion shows that the anomalous torque appears to have a magnitude comparable to one neutral beam source, with the torque peaked at the edge of the plasma. Meaningful studies of momentum confinement must account for this intrinsic rotation/anomalous torque.

[1]Work supported by US DOE under DE-AC02-76CH03073 and DE-FC02-04ER54698.

10:20AM NM4.00003 Momentum Transport Studies in NSTX[1] , STANLEY KAYE, WAYNE SOLOMON, Princeton Plasma Physics Laboratory, NSTX TEAM — The momentum diffusivity in NSTX is low, $< \chi_i$, and it does not scale with the ion thermal diffusivity, as at conventional aspect ratio, possibly due to suppression of ITG modes due to high ExB shear. Dedicated confinement scans show that, if anything, the χ_ϕ scales with χ_e. Perturbative studies of momentum transport have recently been performed on NSTX using n=3 non-resonant braking as a means of perturbing the rotation profile. Braking was applied for 50 ms during a relatively MHD-quiescent phase of the discharge, after which the evolution of the plasma rotation was measured. The non-local torque perturbation created by the n=3 error field created some distortion to the toroidal rotation profile, allowing the separation of momentum flux caused by diffusion (proportional to the gradient in the toroidal rotation) and a momentum pinch (proportional to the toroidal rotation). Preliminary analysis indicates the necessity of a momentum pinch to explain the profile evolution. The effect of off-diagonal terms in the momentum balance equation (eg grad(Ti), grad(ne)) are also considered.

[1]This work has been supported by U.S. DOE Contract # DE-AC02-76CH03073.

10:35AM NM4.00004 Angular momentum transport TCV Ohmic plasmas , ALESSANDRO BORTOLON, BASIL DUVAL, ALEXANDER KARPUSHOV, ANTOINE POCHELON, Ecole Polytechnique Federale de Lausanne (EPFL) Centre de Recherches en Physique des Plasmas (CRPP), Association Euratom-Confederation Suisse, CH-1015, ANDREA SCARABOSIO, Max-Planck Institut für Plasmaphysik, IPP Garching, D-85748 Garching, Germany — Experimental characterization of the momentum transport in the basic scenario of L-mode Ohmic tokamak plasmas is important, since it is a primary test case for any proposed momentum transport model. This scenario has been extensively explored in the TCV tokamak, using a CXRS diagnostic, that is able to measure time resolved toroidal rotation profiles in discharges with negligible momentum input. For both plasmas in limited and diverted magnetic configurations, non-diffusive radial fluxes dominate the angular momentum transport, and the existence of distinct momentum transport regimes was demonstrated. We will assess the stationary rotation profile dependence on plasma parameters, and use transient evolutions (such as spontaneous inversion of rotation direction) to characterize the non-diffusive part of momentum fluxes (magnitude, direction and profile). The role of edge rotation and core MHD activity (sawteeth) will be addressed.

10:50AM NM4.00005 Formation and saturation of zonal flows via turbulent momentum transport in a basic magnetized plasma experiment , GEORGE TYNAN, JONATHAN YU, ZHENG YAN, CHRIS HOLLAND, STEFAN MULLER, MIN XU, Center For Energy Research, OZGUR GURCAN , PATRICK DIAMOND, Center for Astrophysics and Space Science — A radially sheared azimuthal plasma fluid flow is observed in a cylindrical magnetized helicon plasma device with no external sources of momentum input and is sustained against collisional dissipation by the turbulent Reynolds stress. Measurements show that the cross-phase between turbulent velocity components determine the detailed shape of the Reynolds stress profile and the resulting time averaged shear layer profile. Recent work also shows the a-periodic formation of radially outward going plasma transport events which are born near the shear layer and which are associated with the slow evolution of the background plasma fluctuations. The results show a clear demonstration of turbulent-driven shear flows via momentum transport, and suggest that such shear flows may become unstable and thereby generate outward going radial transport events.

11:10AM NM4.00006 Toroidal Rotation in the Torpex Magnetized Plasmas , BENOIT LABIT, AHMED DIALLO, AMBROGIO FASOLI, IVO FURNO, DAVOUD IRAJI, PAOLO RICCI, CHRISTIAN THEILER, Centre de Recherche en Physique des Plasmas - EPF Lausanne — Rotation and plasma flow in general are closely tied to transport of heat and particles across field lines. Toroidal velocity measurements obtained with a Mach probe and covering the entire poloidal cross-section of the TORPEX device ($n_e \leq 10^{17}$m^{-3}, $T_e \leq 10$eV, R=1m, a=0.2m) are presented. It is found that the time averaged toroidal velocity profile does not change when the toroidal magnetic field is reversed. In addition, dependencies of the time averaged toroidal velocity on the vertical magnetic field, the neutral gas pressure and the neutral gas type is investigated and will be compared with theoretical predictions. On TORPEX, a regime has been identified, in which a core plasma is produced and confined on the device high field side, separated from an SOL-like region on the low-field-side. Blobs are observed in this regime to carry plasma from the core to the SOL region. We are investigating the possible impact of the blob propagation on the plasma toroidal rotation using time resolved measurements of the toroidal velocity. It is found that the plasma decelerates when a blob is propagating radially.

11:25AM NM4.00007 Developments in the Theory of Toriodal Momentum Transport[1] , P.H. DIAMOND, C. MCDEVITT, O.D. GURCAN, University of California, San Diego, La Jolla, CA 92093-0424 USA, T.S. HAHM, Princeton Plasma Physics Laboratory, Princeton, NJ 08543-0451 USA — In this talk, we will review and discuss recent developments in the theory of toroidal momentum transport and intrinsic rotation. Special emphasis will be placed on physics mechanisms which underlie the non-diffusive momentum flux, in both its pinch and residual stress components. Electric field shear, toroidicity and wave momentum exchange effects are analyzed. The outlook for future investigations involving energetic particle driven Alfven waves and their effect on momentum transport will be discussed. We also discuss a new class of momentum transport bifurcations.

[1]This work was supported by DoE Grant No. DE-FG02-04ER54738

11:55AM NM4.00008 Edge flows and their role in intrinsic rotation and the LH transition[1] , AHMET Y. AYDEMIR, Institute for Fusion Studies, The University of Texas at Austin — As we enter the era of next-step devices like ITER, where external momentum sources may prove insufficient, intrinsic mass flows are becoming increasingly relevant because of their importance in macroscopic stability and transport. There are flows in tokamaks driven purely by the toroidal geometry itself, making them an integral part of all tokamak plasmas. Related to the Pfirsch-Schlüter fluxes and dipolar in nature, these flows are localized to the edge region because of temperature gradients. Within the separatrix they are essentially cross-field, accompanied by parallel flows in the scrape-off layer (SOL) that tend to provide global mass conservation. In a symmetric system, the toroidal component of the SOL flows has no net angular momentum; however, asymmetries introduced, for example, by a single-null field geometry, results in a net momentum source at the edge. Coupled with an effective inward momentum transport mechanism (e.g., momentum pinch), this source can drive an intrinsic core rotation in the absence of any external momentum source. These flows also have the correct symmetry properties to account for the increased power threshold for the LH transition when the grad-B drift is in the "wrong" direction.

[1]Supported by the US Department of Energy.

12:15PM NM4.00009 Angular momentum sources in tokamak plasma edge , CHOONG-SEOCK CHANG, New York University — Computational study of spontaneous rotation phenomena in a diverted tokamak edge plasma is performed using an edge kinetic code XGC. XGC is capable of simulating the whole edge plasma (including the closed and open magnetic field regions) in the presence of magnetic separatrix and material wall. Full function ions, electrons, and Monte Carlo neutrals are followed in the Lagrangian equation of motion. Conserving Coulomb collisions are used. Three spontaneous rotation sources have been identified in a turbulence-free edge plasma: 1) Electrostatic sheath interaction with material wall in the scrape-off region, 2) Particle orbit loss through the magnetic separatrix and X-point, and 3) steep plasma gradient in the edge pedestal. These three rotation sources combine to produce a 2D spontaneous edge rotation profile. Neutral particle interaction is observed to modify the edge plasma rotation profile. XGC finds that the resonance magnetic perturbation (RMP) can also change the spontaneous edge rotation significantly.

Wednesday, November 14, 2007 9:30AM - 11:30AM –
Session NM5 What's Next for Helicon Sources? Rosen Centre Hotel Salon 11/12

9:30AM NM5.00001 Dual-Source Operation of the HelCat (Helicon-Cathode) Device[1] , CHRISTOPHER WATTS, MARK GILMORE, ALAN LYNN, RALPH KELLY, SHUANWEI XIE, LINCAN YAN, YUE ZHANG, University of New Mexico — The HelCat (Helicon-Cathode) device is a dual-source linear plasma device that has recently begun full operation at the University of New Mexico. HelCat is 4 m long, 50 cm diameter, with axial magnetic field < 2.2 kG. An RF helicon source of tunable frequency 10 – 30 MHz and P < 5 kW, resides at one end of the device, while a thermionic BaO-Ni cathode capable of discharge currents up to 2.5 kA is located at the other end. Nominal parameters are: $T_e \sim 5-10$ eV, $n_e \sim 10^{18}$ m^{-3} (cathode), 10^{19}-10^{20} m^{-3} (helicon), plasma diameter 15 – 20 cm. Diagnostics now online include electrostatic and magnetic probes, mm wave interferometry, visible spectroscopy, Mach probes, and LIF. We present first results of operation with both sources simultaneously.

[1]Work supported by the U.S. D.o.E. under Grant no. DE-FG02-04ER54791 & DE-FG02-06EF54895.

9:50AM NM5.00002 Development and Characterization of Inverted Helicon Plasma Sources , BENJAMIN MASTERS, DAVID RUZIC, University of Illinois at Urbana-Champaign, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM — Helicon plasmas are useful as hot, dense sources requiring low magnetic fields. Since Boswell's[1] use of helicon waves in low pressure gas, research has strived to determine the wave-plasma coupling mechanism. Trivelpiece-Gould (TG) modes[2] remain a strong candidate. An inverted helicon plasma source uses a Nagoya Type III dielectric-covered helicon antenna, placed within a vacuum chamber. The antenna is 8.2 cm long, 2.2 cm in radius, using an frequency of 13.56 MHz. Basic dispersion relation theory is developed as an extension of existing helicon theory which includes TG modes and annular helicons[3]. With this arrangement, diagnostic measurements are made inside and outside the antenna volume. To characterize the plasma, an RF-compensated Langmuir probe measures ne and Te, and 3 B-dot probes measure the field shape of the R, Theta and Z components about the antenna region in the R and Z directions. Typical ne and Te in an Ar plasma were found to be $3\times10^{18}/m^3$ and 3 eV. The goal of this work is to find another configuration to determine the method of efficient plasma heating. [1] R.W. Boswell, Phys. Lett. 33A, 457 (1970) [2] A.W. Trivelpiece and R.W. Gould, Jour. App. Phys. 30 (11) (1959) [3] M. Yano and M.L.R. Walker, Phys. of Plasmas. 13 (063501) (2006)

10:10AM NM5.00003 The Toroidal Helicon Experiment at IPR , MANASH KUMAR PAUL, Institute for Plasma Research, Bhat, Gandhinagar-382428, India — Successful demonstration of plasma current drive by low-frequency bounded whistlers, launched in a toroidal vacuum chamber of small aspect ratio, near lower-hybrid frequency, motivated the novel study of wave induced helicity current drive in helicon wave generated plasma. Helicon discharge, produced in a toroidal vacuum chamber of small aspect ratio, shows strong poloidal asymmetry in the wave magnetic field components. Owing to this strong poloidal asymmetry in the wave magnetic field structures, a nonresonant current is driven in plasma by the dynamo electric field, which arise due to the wave helicity injection by helicon waves. Simultaneous rise in wave helicity is observed when the input RF power is increased. Study of parametric dependence of plasma current in very high frequency operating regime, along with numerical estimations of nonresonant components, has been done. Based on the excitation of toroidal bounded whistlers, which sustain the discharge, a new approach to the problem of current drive is discussed. Close agreement between the numerical estimations and the experimentally obtained plasma current magnitudes clearly delineates the plasma current due to wave-induced helicity from other possible resonant or nonresonant sources at present parameter regime. Preliminary results of helicon current drive experiments and comparison with the numerical estimations are presented.

10:30AM NM5.00004 Ar + CO_2 and He + CO_2 Plasmas in ASTRAL , R.F. BOIVIN, A. GARDNER, J. MUNOZ, O. KAMAR, S. LOCH, Physics Department, Auburn University, 206 Allison Laboratory, Auburn, AL 36849-5311 — Spectroscopy study of the ASTRAL helicon plasma source running Ar + CO_2 and He + CO_2 gas mixes is presented. ASTRAL produces plasmas with the following parameters: $n_e = 10^{10}$ - 10^{13} cm^{-3}, T_e = 2 - 10 eV and T_i = 0.03 - 0.5 eV, B-field $\leq$ 1.3 kGauss, rf power $\leq$ 2 kWatt. A 0.33 m scanning monochromator is used for this study. Using Ar + CO_2 gas mixes, very different plasmas are observed as the concentration of CO_2 is changed. At low CO_2 concentration, the bluish plasma is essentially atomic and argon transitions dominate the spectra. Weak C I and O I lines are present in the 750 - 1000 nm range. At higher CO_2 concentration, the plasma becomes essentially molecular and is characterized by intense, white plasma columns. Here, spectra are filled with molecular bands (CO_2, CO_2^+, CO and CO^+). Limited molecular dissociative excitation processes associated with the production of C I and O I emission are also observed. On the other hand, He + CO_2 plasmas are different. Here, rf matches are only possible at low CO_2concentration. Under these conditions, the spectra are characterized by strong C I and O I transitions with little or no molecular bands. Strong dissociative processes observed in these plasmas can be link to the high T_e associated with He plasmas. An analysis of the spectra with possible scientific and industrial applications will be presented.

10:50AM NM5.00005 Results from the mini-Helicon Thruster Experiment , OLEG BATISHCHEV, NAREG SINENIAN, MURAT CELIK, MANUEL MARTINEZ-SANCHEZ, MIT, Cambridge, MA 02139 — A mini-Helicon Thruster Experiment (mHTX) was designed to study possible space applications. High beam and gas utilization efficiencies are of major importance, as well as the compact design and system integration. We target gases with intermediate weight as diatomic nitrogen, monoatomic argon, and mixtures like air, operating at low <1kW 13.56MHz RF power. We find that higher magnetic fields ~0.2-0.4T in a non-uniform configuration allow shortening the plasma source and achieving intensive collimated exhaust plume. Applied magnetic field is created by copper electromagnets and/or by permanent rare-earth magnets. Application brings other particularities to the design that will be mentioned. The mHTX gas discharge is characterized with UV-VIS spectroscopy using portable spectroscopic system. It shows high >90% gas-to-plasma utilization. High resolution ~0.01A allows measuring Doppler shift of the plume, which appears to be on the order of 10-20km/s. To articulate ionic line shift boron impurity seed is attempted. Emission data are cross-correlated with direct measurements of plasma parameters using various plasma probes and direct thrust-balance data. Additional diagnostics include those for the matching network and wall heat fluxes to analyze the circuit, plasma resistance, RF-to-plasma coupling and power redistribution.

11:10AM NM5.00006 Power Balance in a Helicon Plasma. , DAN BERISFORD, Univ of Texas at Austin, LAXMINARAYAN RAJA, ROGER BENGTSON, CHARLES LEE — We present results of a series of experiments exploring the mechanisms of power flow in a helicon plasma. The power absorbed by the plasma ultimately flows out in the form of heat through various channels. An infra-red camera records images of the quartz dielectric confinement tube outer surface, from which we calculate the total power lost to the glass as a function of position. Inside the vacuum chamber, Langmuir probes measure plasma density and temperature profiles, and bolometers measure the radial energy flux near the plasma edge. RF current and voltage sensors measure the forward power delivered to the plasma. Using these diagnostics, we can account for most of the input power, and we see that a large portion of the power is lost radially to the walls of the dielectric confinement tube.

Wednesday, November 14, 2007 2:00PM - 3:00PM – Session PT1 Tutorial: Scientific Challenges of Burning Plasmas Rosen Centre Hotel Junior Ballroom

2:00PM PT1.00001 The Scientific Challenge of Burning Plasmas[1] , JAMES W. VAN DAM, US Burning Plasma Organization — The next frontier for fusion is the study of burning plasmas. The ITER facility, to be operated as an international project, will push research efforts into this new regime. In this tutorial, we will first define a burning plasma and describe its distinguishing properties. One such feature is dominant self-heating (exothermic) by a large population of alpha particles, created from thermonuclear reactions. Fusion self-heating also leads to strongly nonlinear coupling of critical elements in MHD stability, transport, alpha particle losses, edge behavior, and burn dynamics. Also, burning plasmas require robust plasma-wall facing components and diagnostics that can withstand high heat and neutron wall loadings. Next, we will briefly review how previous experiments on JET and TFTR to attain break-even ($Q\leq1$) have laid the foundation for taking the present step to ITER. Then, we will describe the various physics issues that need to be addressed for burning plasmas, both in preparation for ITER and also when operating at high fusion gain (Q=5-10). Examples of near-term research needs for ITER include the time-dependent study of start-up flexibility to determine whether suitable hybrid and steady-state plasmas can be produced; analysis of the possibility of integrated control of resistive wall modes, ELMs, neoclassical tearing modes, and error field effects; and loss of alpha particles and also beam and RF-heated fast ions due to magnetic field ripple and wave-particle resonances. In high-gain operation, the understanding of pressure limits for stability and turbulent transport for confinement (including pedestal and transport barrier dynamics) must be extended to large size (gyroradius much less than minor radius). Burning plasma operation will also require methods for dealing with tritium retention and replenishment. Other research opportunities will also be described.

[1]Work supported by OFES-USDOE.

Wednesday, November 14, 2007 2:00PM - 3:00PM –
Session PI2 Education and Outreach Rosen Centre Hotel Salon 3/4

2:00PM PI2.00001 Educating the next generation in the science and technology of plasmas, beams and accelerators[1] , WILIAM BARLETTA, USPAS, Fermilab, and Dept. of Physics, MIT — Accelerators are essential tools for discovery in fundamental physics, biology, and chemistry. Particle beam based instruments in medicine, industry and national security constitute a multi-billion dollar per year industry. More than 55,000 peer-reviewed papers having accelerator as a keyword are available on the Web. Yet only a handful of universities offer any formal training in accelerator science. Several reasons can be cited: 1) The science and technology of non-neutral plasmas cuts across traditional academic disciplines. 2) Electrical engineering departments have evolved toward micro- and nano-technology and computing science. 3) Nuclear physics departments have atrophied. 4) With few exceptions, interest at individual universities is not extensive enough to support a strong faculty line. The United States Particle Accelerator School (USPAS) is National Graduate Educational Program that has developed an educational paradigm that, over the past twenty-years, has granted more university credit in accelerator / beam science and technology than any university in the world. Governed and supported by a consortium of nine DOE laboratories and two NSF university laboratories, USPAS offers a responsive and balanced curriculum of science, engineering, and hands-on courses. Sessions are held twice annually, hosted by major US research universities that approve course credit, certify the USPAS faculty, and grant course credit. The USPAS paradigm is readily extensible to other rapidly developing, cross-disciplinary research areas such as high energy density physics.

[1]This work has been partially supported by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the United States Department of Energy.

2:30PM PI2.00002 Plasma Physics Research at an Undergraduate Institution , STEPHEN PADALINO, The State University of New York at Geneseo — Undergraduate research experiences have motivated many physics majors to continue their studies at the graduate level. The Department of Physics and Astronomy at SUNY Geneseo, a primarily undergraduate institution, recognizes this simple reality and is committed to ensuring research opportunities are available to interested majors beginning as early as their freshman year. Every year for more than a decade, as many as two dozen students and 8 faculty members have worked on projects related to high energy density physics and inertial confinement fusion during the summer months and the academic year. By working with their research sponsors, it has been possible to identify an impressive number of projects suitable for an institution such as Geneseo. These projects tend to be hands-on and require teamwork and innovation to be successful. They also take advantage of in-house capabilities such as the 2 MV tandem pelletron accelerator, a scanning electron microscope, a duoplasmatron ion deposition system and a 64 processor computing cluster. The end products of their efforts are utilized at the sponsoring facilities in support of nationally recognized programs. In this talk, I will discuss a number of these projects and point out what made them attractive and appropriate for an institution like Geneseo, the direct and indirect benefits of the research opportunities for the students and faculty, and how the national programs benefited from the cost-effective use of undergraduate research. In addition, I will discuss the importance of exposure for both students and faculty mentors to the larger scientific community through posters presentations at annual meetings such as the DPP and DNP. Finally, I will address the need for even greater research opportunities for undergraduate students in the future and the importance of establishing longer "educational pipelines" to satisfy the ever growing need for top-tier scientists and engineers in industry, academia and the national laboratories.

Wednesday, November 14, 2007 2:00PM - 4:48PM –
Session PO3 C-Mod Tokamak Rosen Centre Hotel Salon 9/10

2:00PM PO3.00001 Overview of Alcator C-Mod Research[1] , EARL MARMAR, Massachusetts Institute of Technology, ALCATOR C-MOD TEAM — C-Mod research has emphasized lower hybrid current profile control, realtime ICRF matching, pedestal studies including large ELMs, SOL turbulence and transport including flow studies, hydrogenic retention in metals, wall conditioning, disruption prediction and mitigation, error fields and locked modes, exploration of lower density and collisionality regimes, and Alfven eigenmodes. Particular attention is given to high priority R&D for ITER and joint experiments coordinated through the ITPA. LHCD experiments have been extended to H-Mode regimes, and in combination with ICRF, with good coupling across the edge plasmas. An important new tool for C-Mod is active density control with a divertor crypump. Improved measurements across all plasma regimes are enabled by new/upgraded diagnostics: high resolution X-Ray crystal spectroscopy; hard X-Ray imaging; active CXRS; bolometry; increased wavenumber spatially localized phase contrast imaging; ultra high speed CCD cameras; IR imaging; swept frequency reflectometry; magnetic pick-ups; and high field side SOL scanning Mach probes.

[1]Supported by USDoE DE-FC02-99ER54512, DE-AC02-76CH03073, ED-FG03-96ER54373, DE-FC02-94ER54235, and W-7405-ENG-48

2:12PM PO3.00002 Experiments with Lower Hybrid Current Drive on Alcator C-Mod[1] , J.R. WILSON, C. KESSEL, C.K. PHILLIPS, S. SCOTT, E. VALEO, PPPL, R. PARKER, P.T. BONOLI, A.E. HUBBARD, J. KO, M. PORKOLAB, A.E. SCHMIDT, G. WALLACE, J. WRIGHT, MIT — In 2006 a new 4.6 GHz lower hybrid system was commissioned on Alcator C-Mod, demonstrating the capability of the system in L-mode plasmas. In 2007 the studies have continued on the basic properties of the wave coupling, absorption and current drive as well as those demonstrating the applicability of LHCD to advanced tokamak plasma conditions. In particular, studies of the formation and decay of the fast electron tail have been performed by utilizing fast modulation of the rf power, and coupling studies in H-mode and ICRF dominated plasmas have been performed, yielding conditions under which combined LH and ICRF operation is possible. Operation over a wider range of plasma density and launcher phase has been performed. Injection of LH power in the current ramp phase of the discharge has delayed the onset of the sawtooth oscillation by up to 0.4 s even at modest, ~400 kW, power levels. Measurements with MSE have been made that indicate a broadening of the current profile and comparison of these with the x-ray emission, non-thermal ECE and simulations will be presented.

[1]Work supported by USDOE DE-FC02-99ER5412 & DE-AC02-76CH03073.

2:24PM PO3.00003 Dimensionless pedestal identity plasmas on Alcator C-Mod and JET , G. MADDISON, M. BEURSKENS, K. ERENTS, M. KEMPENAARS, S. LISGO, UKAEA-1, A. HUBBARD, J. HUGHES, J. SNIPES, M. PORKOLAB, L. LIN, PSFC MIT-2, I. NUNES, CFN-IST, R. PASQUALOTTO, RFX-CNR, E. GIOVANNOZZI, FTU-ENEA, EFDA-JET CONTRIBUTORS TEAM — Scaling of the H-mode pedestal is crucial for standard scenarios in ITER, but remains uncertain eg owing to the unresolved balance between plasma transport and edge source effects. This can be clarified using plasmas on different tokamaks with identical shape and dimensionless variables at the pedestal top, for which local transport should be the same. ELM-free H-modes at 7.9T, 1.3MA on C-Mod correspond to 1.4T, 0.9MA counterparts on JET, where a power scan in natural-density H-modes with small ELMs matched pedestal identity conditions for higher C-Mod densities. Measurements with a new Thomson scattering diagnostic indicated JET profile widths may be slightly wider than scaled C-Mod values. Modelling of refuelling terms in each device will compare their relative contributions to pedestal structures. Edge magnetic and density fluctuations will also be contrasted.

[1]Funded jointly by the UK EPSRC and by the EC under the CoA between EURATOM and UKAEA.
[2]Supported by US DOE award DE-FC02-99ER54512.

2:36PM PO3.00004 H-mode performance and pedestal studies with enhanced particle control on Alcator C-Mod[1]

, J.W. HUGHES, B. LABOMBARD, M. GREENWALD, A. HUBBARD, B. LIPSCHULTZ, K. MARR, R. MCDERMOTT, M. REINKE, J.L. TERRY, MIT PSFC, W.L. ROWAN, I.O. BESPAMYATNOV, Fusion Research Center, UT-Austin — H-mode density control studies are extended on the Alcator C-Mod tokamak with the recent implementation of an upper chamber cryopump. Experiments have examined the effects of strong neutral pumping on H-mode edge pedestal profiles and core fueling, in varied magnetic topology (both lower and upper null, and close to balanced double null), and over a significant range in edge density. As in prior H-mode puffing experiments, these studies are meant to examine H-mode fueling in discharges with edge neutral opacity approximating that expected in ITER. Significant reduction of edge collisionality is observed with enhanced pumping, concurrent in many cases with high H-mode performance and core density peaking. Cryopumping provides a new tool for obtaining steady H-modes with sustained low collisionality, allowing for continued exploration of pedestal fueling studies, critical-gradient behavior of plasma profiles and access conditions to H-mode regimes (e.g. EDA, ELM-free, ELMy).

[1]Supported by USDoE grants DE-FC02-99-ER54512, DE-FG03-97-ER54415.

2:48PM PO3.00005 Particle transport and density peaking at low collisionality on Alcator C-Mod[1]

, M. GREENWALD, MIT-Plasma Science & Fusion Center, J.W. HUGHES, MIT, D. MIKKELSEN, PPPL, J. TERRY, MIT — While H-modes tend to have very flat density profiles, modest density peaking is advantageous for fusion performance. Thus robust pinch mechanisms that could allow operation with peaked profiles, in the absence of any internal particle source, are of considerable interest. Recent experiments on C-Mod[1], at low collisionality, show just such peaking and are quantitatively consistent with earlier results from ASDEX-U[2] and JET[3]. By extending the range in machine size, these data break the covariance between collisionality and n/n_G, the density normalized to the density limit and strongly support the primary role of collisionality in determining the profile. The implication is that ITER will have density profiles with $n_e(0)/\langle n_e\rangle \simeq 1.4-1.6$. The C-Mod data also show a small but statistically significant dependence of the peaking factor on the edge safety factor, q. The effect is to increase the peaking by no more than 10% when q is raised from 3.5 to 5.Initial studies of gyrokinetic simulations for these discharges will be shown. [1]M. Greenwald, submitted to Nucl. Fusion, 2007 [2]C. Angioni, et al., PRL 90, 205003, 2003 [3]H.Weisen, Nucl. Fusion 45, L1, 2005

[1]Supported by USDoE award DE-FC02-99ER54512

3:00PM PO3.00006 Ohmic ITBs in Alcator C-Mod[1]

, C.L. FIORE, MIT-PSFC, W.L. ROWAN, UT-FRC, A. DOMINGUEZ, A.E. HUBBARD, A. INCE-CUSHMAN, M.J. GREENWALD, L. LIN, E.S. MARMAR, M. REINKE, J.E. RICE, K. ZHUROVICH, MIT-PSFC — Internal transport barrier plasmas can arise spontaneously in ohmic Alcator C-Mod plasmas where an EDA H-mode has been developed by magnetic field ramping. These ohmic ITBs share the hallmarks of ITBs created with off-axis ICRF injection in that they have highly peaked density and pressure profiles and the peaking can be suppressed by on-axis ICRF. There is a reduction of particle and thermal flux in the barrier region which then allows the neoclassical pinch to peak the central density. Recent work on ITB onset conditions [1] which was motivated by turbulence studies [2] points to the broadening of the T_i profile with off-axis ICRF acting to reduce the ion temperature gradient. This suppresses ITG instability driven particle fluxes, which is thought to be the primary mechanism for ITB formation. The object of this study is to examine the characteristics of ohmic ITBs to find whether the stability of plasmas and the plasma parameters support the onset model.

[1]K. Zhurovich, et al., To be published in Nuclear Fusion
[2] D. R. Ernst, et al., Phys. Plasmas 11, 2637 (2004)

[1]Work supported by USDOE Grant DE-FG03-96ER54373 and Coop. Agree. No. DE-FC02-99-ER54512.

3:12PM PO3.00007 Hydrogenic Fuel Retention in Molybdenum

, D.G. WHYTE, B. LIPSCHULTZ, J. IRBY, PSFC-MIT, G.M. WRIGHT, FOM-Rijnhuizen — High-Z refractory metals such as tungsten and molybdenum (Mo) are favored as plasma-facing components in burning plasma experiment to minimize hydrogenic (H) fuel retention, mainly due to their low H solubility (~1 appm). Fuel retention in Mo is studied and modeled in the Mo-tile Alcator C-Mod tokamak, and DIONISOS a new facility that features simultaneous plasma bombardment and real-time retention diagnosis. We find that high ion fluxes leads to D trap sites in the Mo; energy wells in which the fuel can reside at concentrations ~ 1%, i.e. much larger than the solubility. The tokamak environment leads to other unique characteristics such as temperature transients through heating and neutron bombardment that further increase retention. High temperature drives D traps and retention deeper into the Mo, but the sudden cooling of the material with removal of the plasma flux "freezes" the D deep in the Mo. This physical model recreates the C-Mod retention result, i.e. that a large fraction (~30%) of the fuelled D can be retained reproducibly over many shots, despite the absence of low-Z film growth. This retention mechanism is fundamentally different than co-deposition of D with carbon, which is observed to dominate D retention in most current tokamaks. The implications for burning plasmas with high neutron loads will be discussed.

3:24PM PO3.00008 Observations of the Spatial and Temporal Structure of Edge Turbulence near the X-point of Alcator C-Mod[1]

, J.L. TERRY, MIT-PSFC, S.J. ZWEBEN, PPPL, B. LABOMBARD, I. CZIEGLER, MIT-PSFC, O. GRULKE, MPI for Plasma Physics — Movies of edge turbulence in the region just outboard of the typical LSN X-point location in C-Mod have been obtained using Gas-Puff-Imaging with a fast-framing (150,000 frames/s) camera. Images of the turbulence in a plane perpendicular to the local field show structures that are highly elongated in the local radial direction. Typically these structures move poloidally, but move only slightly outward in the elongation direction. Both the structure and the motion of the turbulent structures as imaged in this location are very different than the nearly circular cross-sectioned "blobs" that are observed near the outer midplane. Field line mapping of circular flux tubes at the midplane show that these are distorted into elongated "fingers" when mapped to the viewing location outboard of the X-point, consistent with the observations. Movies of the edge turbulence through L-to-H-mode transitions show no obvious precursor and typically show only a brief (~1 ms) quiescent period after the transition.

[1]Supported by USDoE awards DE-FC02-99ER54512 and DE-AC02-76CH03073.

3:36PM PO3.00009 Interpretation of Edge Turbulence Images near the X-point of Alcator C-Mod[1]

, STEWART ZWEBEN, PPPL, JAMES TERRY, BRIAN LABOMBARD, MARTIN GREENWALD, MIT, OLAF GRULKE, IPP, RONALD COHEN, DMITRI RYUTOV, MAXIM UMANSKY, LLNL, TIM STOLTZFUS-DUECK, JOHN KROMMES, PPPL — Recent images of edge turbulence taken just outboard of the typical X-point location in Alcator C-Mod show a very different structure and motion from those taken near the outer midplane (see previous talk). We interpret these differences using a model in which the structures are formed near the outer midplane and affect the X-point region through fluctuations propagating along the field lines (most likely electrostatic potential fluctuations). The structural differences are then due to the shearing and flux expansion of the magnetic field between the outer midplane and the X-point, which distort circular 'blobs' at the midplane into radial 'fingers' near the X-point. Various tests of this model will be discussed and a comparison of the near-X-point images with a BOUT simulation will be described.

[1]supported by U.S. DOE Contracts DE-AC02-76CH03073 and No. DE-FC02-99ER5412

3:48PM PO3.00010 Structure of the Broadband Edge Turbulence in L-mode and pre-H-mode Plasmas in Alcator C-Mod[1] , I. CZIEGLER, J.L. TERRY, B. LABOMBARD, PSFC-MIT — The edge and near SOL turbulence at the outboard midplane region of ohmic L-mode plasmas have been investigated using gas-puff-imaging and probe measurements. Poloidal wave number information was obtained by a vertical array of views (approximately aligned with a flux-surface) with a 1 MHz sampling rate. We characterized the structure of the broadband turbulence over a range of minor radii that extends both in- and outside the separatrix for various plasma densities, magnetic configurations (LSN, DN, USN) and toroidal fields with a fixed safety factor. The observed dispersion relations show a strong radial structure: the turbulence propagates in the ion- diamagnetic direction at and outside the separatrix, and moves in the electron-diamagnetic direction just inside the separatrix. The dispersions are largely linear with velocities consistent with probe measurements (1.5–2 km/s in the ion, 3.5–4 km/s in the electron direction), yet seem to be inconsistent with a simple sheared flow model. The turbulence structure shows an observable variation in and just prior to L- H transition periods.

[1]Supported by USDoE award DE-FC02-99ER54512.

4:00PM PO3.00011 First Measurements of Total Flow Vector in the C-Mod High-Field Side SOL[1] , NOAH SMICK, BRIAN LABOMBARD, MIT PSFC, ALCATOR C-MOD TEAM — A new four-electrode scanning Langmuir probe has been installed and operated on the high-field side of Alcator C-Mod. The *WASP* (Wall-Actuated Scanning Probe) has the ability to take data as deep as a few mm inside the LCFS and to measure the total flow vector (parallel and cross-field) as well as fluctuation-induced fluxes using a tungsten-tipped Gundestrup probe. The WASP has verified many of the plasma flow results reported previously using a single-electrode scanning probe [1], as well as adding some important new observations. Near-sonic parallel flows are observed in the far SOL which reverse direction when the topology is reversed. However, their behavior near the separatrix is different. Parallel flows near the separatrix appear to be clamped near zero in LSN but remain high in USN for normal field direction. Cross-field flows show a region of high shear at the radial location of steep pressure gradients, a feature that is also seen on C-Mod's low-field side scanning probes. These and other new results from the WASP will be presented.

[1] B. LaBombard et al., Nucl. Fusion **44** (2004) 1047.

[1]supported by U.S. DOE Agreement DE-FC02-99ER54512.

4:12PM PO3.00012 Plasma flows due to blobs and drifts in Alcator C-Mod scrape-off layer[1] , A.YU. PIGAROV, S.I. KRASHENINNIKOV, UCSD, B. LABOMBARD, MIT, T.D. ROGNLIEN, LLNL — Long-range near-sonic parallel plasma flows in Alcator C-Mod tokamak scrape-off (SOL) layer are measured and modelled with UEDGE (2D multi-fluid plasma/neutral transport code). As shown, the dominant mechanism driving such flows is fast non- diffusive intermittent cross-field transport (due to blobs) which is modelled as anomalous convection of ion species with strong ballooning-like poloidal asymmetry (HFS/LFS<1/10). Here, the properties of asymmetric-transport driven flows, main chamber and divertor recycling, as well as divertor detachment are studied with UEDGE. The conditions for zonal and circular plasma flow patterns in the SOL are analyzed. The impact of $E\times B$ and ∇B plasma drifts on non-diffusive transport driven flows is modelled and discussed.

[1]Work supported by research grant DE-FG02-04ER54739 at UCSD.

4:24PM PO3.00013 Fast Electron Driven Alfvén Eigenmodes in Alcator C-Mod[1] , J.A. SNIPES, R.R. PARKER, A. SCHMIDT, G. WALLACE, MIT PSFC — Injecting 300 – 500 kW of Lower Hybrid Current Drive (LHCD) at the very beginning of the discharge, a series of high frequency (200 – 800 kHz) bursting magnetic fluctuations are observed. There are three sets of modes in ms bursts separated by about 100 kHz with the frequency and time separation of the bursts increasing logarithmically in time. The modes begin about 2.5 ms after the start of the LHCD pulse and persist as long as the plasma is well coupled to the LH grill. The mode amplitudes, measured with pick-up coils on the outboard limiter, reach $\tilde{B}_\theta \approx 2\times10^{-5}$ T. The frequency sweeping and amplitude of these modes are similar to those of ICRF fast ion driven Alfvén cascades in the current rise[1], but instead are driven by fast electrons and rotate in the electron diamagnetic drift direction. The bursting behavior of the modes is similar to neutral beam driven fishbones[2]. Measurements with a hard x ray imaging array indicate that the fast electron energy reaches up to 80 keV in these very low density plasmas ($\bar{n}_e \leq 2\times10^{19}$ m^{-3}).

[1] J A Snipes, et al, *Phys. Plasmas* **12** (2005) 056102. [2] K McGuire, et al, *Phys. Rev. Lett.* **50** (1983) 891.

[1]Supported by USDoE award DE-FC02-99ER54512.

4:36PM PO3.00014 First Results From The New High Resolution Imaging X-ray Crystal Spectrometer On Alcator C-Mod , ALEXANDER INCE-CUSHMAN, JOHN RICE, MIT, MANFRED BITTER, PPPL, MATHEW REINKE, MIT, KENNETH HILL, STEVEN SCOTT, PPPL — In an effort to improve the diagnostic capabilities for measuring plasma rotation on Alcator C-Mod, an imaging x-ray spectrometer has been designed and installed. This instrument utilizes a spherically bent quartz crystal and a set of 2D x-ray detectors to image the entire plasma cross section with a spectral resolving power of approximately 10,000 with vertical spatial resolution of about 1cm. Line emission from highly ionized states of argon and molybdenum are measured at frame rates up to 200Hz. Using spectral tomographic techniques the line integrated spectra can be inverted to determine impurity density, velocity and temperature profiles. An overview of the instrument, analysis and example profiles are presented. Work supported by USDoE Coop. Agree. No. DE-FC02-99ER54512 & DE-AC02-76CH03073.

Wednesday, November 14, 2007 2:00PM - 5:00PM – Session PO6 Hydrodynamic Instability Rosen Centre Hotel Salon 5/6

2:00PM PO6.00001 Equal-Channel-Angular-Extrusion Be-Cu as a NIF Ablator[1] , J.A. COBBLE, T.E. TIERNEY, B.G. DEVOLDER, I.L. TREGILLIS, N.M. HOFFMAN, R.D. DAY, A. NOBILE, LANL — Equal channel angular extrusion (ECAE) Be-Cu is an alloy that may be useful as an ignition target ablator at the National Ignition Facility (NIF). Planar samples have been diamond turned to create a 0.25-μm amplitude sinusoid on one side. These have been mounted in hohlraum targets at the OMEGA laser and driven by a pressure approaching 2 Mbar and a radiation temperature that peaks near 160 eV in ~6 ns. The resulting growth of the Rayleigh-Taylor instability has been examined with x-ray backlighting. With face-on imaging, we see no growth. However, with side-on radiography, parallel the grooves of the sinusoid, the twenty-times-greater ρr permits us with a 16-frame gated x-ray imager to see modulation of the Be-Cu foil as it is launched out of the end of the hohlraum. The x-ray transmission is deduced. Hydrodynamic modeling matches the radiation temperature of the hohlraum, and calculations are compared to the velocity of ejection of the sample. A 2D-Rad-Hydro code is used to calculate the sample mean x-ray mass absorption coefficient for the broadband backlighter energy. The time-dependent growth factor of the instability is estimated.

[1]This work is done under the auspices of the United States Department of Energy contract number DE-AC52-06NA25396.

2:12PM PO6.00002 NIF-ablator characterization experiments on the Omega laser system[1]

, DAVID BRADLEY, D.G. BRAUN, G.W. COLLINS, S.W. HAAN, S.G. GLENDINNING, R.H. PAGE, J.L. MILOVICH, O. LANDEN, Lawrence Livermore National Laboratory, V. SMALYUK, Laboratory for Laser Energetics, A. NIKROO, K. MORENO, H. HUANG, General Atomics — A detailed understanding of the performance of candidate ablator materials is important for guiding the design of indirect drive ICF capsules for ignition. This includes, but is not limited to understanding measurements of preheat and instability growth. We have previously reported on the development of a high-growth planar Rayleigh Taylor platform in which we have demonstrated growth factors of 200x for sinusoidal 2-D modulations in CH foils. The technique has now been adapted to study 3D surface perturbations in actual NIF ablator materials. In this presentation we show the results of experiments carried out on sputtered Cu-doped Be with random surface perturbations at levels close to those expected on the NIF ignition capsule.

[1]This work was performed under the auspices of U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

2:24PM PO6.00003 Simulations of high-mode Rayleigh-Taylor growth in NIF ignition capsules[1]

, B.A. HAMMEL, M.J. EDWARDS, S. HAAN, M. MARINAK, M. PATEL, H. ROBEY, J. SALMONSON, Lawrence Livermore National Laboratory — The inner surface smoothness requirement for NIF ignition capsules is driven by maintaining acceptable Rayleigh-Taylor (R-T) growth at the pusher/fuel interface. During the implosion, the DT fuel reaches higher density than the pusher material accelerating it. Growth near this interface is stabilized only by density gradient effects, plasma viscosity and mass diffusion. The density gradient is influenced by thermal conduction across the interface, in response to the difference in temperature in the x-ray absorbing pusher and the relatively transparent fuel. Thermal conduction models are uncertain in this regime ($\sim$10 g/cc and $\sim$30 eV), and may be significant in determining the overall R-T growth. The growth can be modified by varying the radial profile of a high-Z dopant in the ablator. To optimize capsule designs, we are performing 2D and 3D HYDRA simulations that resolve up to mode $\sim$2000. The results of this work will be presented.

[1]This work was performed under the auspices of U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

2:36PM PO6.00004 Effects of viscosity and mass diffusion on the Richtmyer-Meshkov instability at the DT-ice/Be interface

, JONATHAN ILORETA, UC Berkeley, HARRY ROBEY, ANDREW COOK, JOHN EDWARDS, LLNL, ANDREW SZERI, UC Berkeley — We use Miranda to simulate the Richtmyer-Meshkov (RM) instability at the DT-ice/Be interface of a National Ignition Facility (NIF) capsule in order to determine the stabilizing effects of viscosity and mass diffusion. The RM instability is driven by the first shock of the NIF drive. The simulations are in planar geometry and the interface includes a finite density gradient. We compare our numerical results with two linear analytical models that include viscous effects and comment on the fits. Preliminary results suggest that a new model that incorporates both viscosity and diffusion can be developed.

2:48PM PO6.00005 Late time nonlinear hydrodynamic instabilities evolution– theoretical and numerical investigation.

, SHVARTS DOV[1], YONATHAN ELBAZ[2], NACHLIEL WYGODA[3], Nuclear Research Center Negev, ISRAEL — The dependence of the instability dynamics on the initial conditions (amplitude and spectrum) was studied numerically and analytically, using a mode coupling extension to Haan's and Ofer's models. Regimes of initial conditions, in which the growth rate of the instabilities are dominated either by the initial conditions or by mode coupling, were identified. Using these modal models in the mode coupling regime we were able to determine the different asymptotic power laws and coefficients of the growth rates of the different instabilities and present new relationships between them. Comparison between the newly derived power laws and those obtained in experiments, full numerical simulations and bubble competition models, in two and three dimensions, will be discussed.

[1]also at the Ben Gurion University, ISRAEL and the Laboratory for Laser Energetics, University of Rochester
[2]also at the Ben Gurion University, ISRAEL
[3]also at the Hebrew University, ISRAEL

3:00PM PO6.00006 Multimode simulations of indirectly-driven high-convergence plastic capsules on Omega[1]

, PETER AMENDT, LLNL — An extensive Omega database of indirect-drive implosions with Ge-doped CH ablators and deuterium (DD) fuel has been developed over the past several years. Previously, nominally smooth capsules with fuel pressures from 5 to 50 atm were successfully analyzed [1] using the weakly nonlinear Haan saturation model. More recently, high-convergence (10 atm DD) targets were fielded with intentionally roughened ablators to test our modeling tools in a more nonlinear regime. Improved hohlraum modeling to accommodate the measured ($\approx$ 2x) enhancement (relative to nominal XSN opacity modeling) in gold M-band (2-5 keV) preheat and the use of thin walls ($\approx$ 2 micron) for non-perturbative diagnosis of core symmetry is implemented. A frequency-dependent source is then extracted to drive separate capsule-only simulations with HYDRA [2] in 2-D. Results of multimode simulations spanning RMS capsule roughness from 10-350 nm are presented and compared with data.

[1] P. Amendt, R.E. Turner, and O.L. Landen, PRL 89, 165001 (2002).
[2] M. Marinak *et al.*, PoP 8, 2275 (2001).

[1]Work performed under the auspices of U.S. Department of Energy by LLNS-LLC under Contract No. W-7405-Eng-48.

3:12PM PO6.00007 Inference of ICF Implosion Core Mix using Experimental Data and Theoretical Mix Models[1]

, L. WELSER-SHERRILL, D.A. HAYNES, J.H. COOLEY, Los Alamos National Laboratory, R.C. MANCINI, University of Nevada, Reno, R. TOMMASINI, S.W. HAAN, Lawrence Livermore National Laboratory, I.E. GOLOVKIN, Prism Computational Sciences, S.P. REGAN, V.A. SMALYUK, Laboratory for Laser Energetics — The mixing between fuel and shell materials in Inertial Confinement Fusion implosion cores is a topic of great interest. Mixing due to hydrodynamic instabilities can affect implosion dynamics and could also go so far as to prevent ignition. The goal of this work was to design direct-drive ICF experiments on OMEGA which have varying levels of mix, and subsequently to extract information on mixing directly from the experimental data using spectroscopic arguments. The experimental design was accomplished using hydrodynamic simulations and Haan's and Youngs' mix models, which make it possible to predict the mix levels of each experimental platform. These theoretical predictions were then compared to the information on mixing which was extracted from the experimental data. We aim to increase our confidence in the methods used to extract mixing information from experimental data, as well as to assess the range of validity and predictive capability of the mix models.

[1]We gratefully acknowledge support from DOE-NLUF grant DE-FG52-2005NA26012.

3:24PM PO6.00008 Irradiation Uniformity in Direct-Drive Simulations Using 3-D Ray Trace

, A. SHVYDKY, D. KELLER, J.A. MAROZAS, P.W. MCKENTY, S. SKUPSKY — A crucial component in calculating the drive uniformity in ICF simulations with direct illumination is a detailed treatment of laser-ray propagation through the plasma atmosphere using information about the orientation of the individual laser beams and nonuniformity structure on the beams. The resulting nonuniformity in laser deposition can contain short-wavelength structure that would not appear in uniformity estimates that simply project laser beams onto a sphere. Further, the ray-trace simulations can be sensitive to details of how well the region around critical density has been resolved in the hydrodynamic simulation. The sensitivity of the resulting target drive to the numerical modeling of the ray-trace physics is discussed. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

3:36PM PO6.00009 Stabilizing effect of anisotropic thermal diffusion on the ablative Rayleigh-Taylor instability

, LAURENT MASSE, CEA, CEA/DAM TEAM — For more than twenty years, numerous analyses have been devoted to the instability of the ablation front in the context of inertial confinement fusion. It has been shown by several authors that the ablative Rayleigh-Taylor instability (RTI) is stabilized during the linear stage in contrast to the classical RTI. The physical origin of the dominant stabilizing effect has been attributed to blow-off convection or dynamical pressure correlated with the rocket effect. First, the work presented here clearly recalls that the main stabilizing effect can be understood as a transversal diffusive mechanism. This understanding suggests that anisotropic diffusion could be used to reduce the ablative RTI growth. In this Letter, we show, both on the basis of a linear theory of the ablative RTI and 2D hydrodynamic simulations, that anisotropic diffusion leads to a strong reduction of the ablative RTI growth rates, the mean flow being left unchanged. We then provide a simple method to produce such an anisotropy, using a laminated structure of the ablated material made up of successive layers of high and low conductivities. Finally, we present numerical simulations of the ablative RTI in a planar experimental configuration, confirming the theoretical predictions.

3:48PM PO6.00010 Rayleigh–Taylor Growth and Spherical Compression Measurements of Silicon-Doped Ablators

, J.P. KNAUER, P.B. RADHA, V.N. GONCHAROV, I.V. IGUMENSCHEV, R. BETTI, R. EPSTEIN, F.J. MARSHALL, S.P. REGAN, V.A. SMALYUK, D.D. MEYERHOFER, S. SKUPSKY — X-ray emission from coronal photons emitted by high-atomic-number (Z) layers has been proposed to shape the adiabat in the shell and reduce ablative Rayleigh–Taylor (RT) growth rates during shell acceleration.[1] This effect has been studied with planar-foil experiments to measure the RT growth and low-adiabat spherical implosions to measure the total areal density for a mid-Z, silicon (Si), dopant using the OMEGA laser. Growth of perturbations at the ablation interface due to the RT instability is sensitive to the outer-shell adiabat. An implosion target's areal density is sensitive to the inner-shell adiabat and is a sensitive measure of preheat of the inner fuel. Plastic (CH) shells and planar foils are doped with Si with an atomic concentration of 4% to 6%. Experimental data are compared with the hydrodynamic modeling of both the ablation-interface RT growth and the spherical implosion total areal density. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] S. E. Bodner *et al.*, Phys. Plasmas **5**, 1901 (1998).

4:00PM PO6.00011 Numerically Simulating Collisions of Plastic and Foam Laser-Driven Foils[1]

, S.T. ZALESAK, A.L. VELIKOVICH, A.J. SCHMITT, Plasma Physics Division, Naval Research Laboratory, Washington, DC, Y. AGLITSKIY, N. METZLER, Science Applications International Corporation — Interest in experiments on colliding planar foils has recently been stimulated by (a) the Impact Fast Ignition approach to laser fusion [1], and (b) the approach to a high-repetition rate ignition facility based on direct drive with the KrF laser [2]. Simulating the evolution of perturbations to such foils can be a numerical challenge, especially if the initial perturbation amplitudes are small. We discuss the numerical issues involved in such simulations, describe their benchmarking against recently-developed analytic results, and present simulations of such experiments on NRL's Nike laser.
[1] M. Murakami *et al.*, Nucl. Fusion **46**, 99 (2006)
[2] S. P. Obenschain *et al.*, Phys. Plasmas **13**, 056320 (2006).

[1]This work was supported by the U.S. Department of Energy.

4:12PM PO6.00012 Collisions of plastic and foam laser-driven foils studied by orthogonal x-ray imaging.[1]

, Y. AGLITSKIY, N. METZLER, Science Applications International Corporation, M. KARASIK, V. SERLIN, S.P. OBENSCHAIN, A.J. SCHMITT, A.L. VELIKOVICH, S.T. ZALESAK, J.H. GARDNER, J. WEAVER, J. OH, Plasma Physics Division, Naval Research Laboratory, Washington, DC, E.C. HARDING, University of Michigan — We report an experimental study of hydrodynamic Rayleigh-Taylor and Richtmyer-Meshkov-type instabilities developing at the material interface produced in double-foil collisions. Our double-foil targets consist of a plastic foil irradiated by the 4 ns Nike KrF laser pulse at ~50 TW/cm^2 and accelerated toward a stationary plastic or foam foil. Either the rear side of the front foil or the front side of the rear foil is rippled. Orthogonal imaging, i. e., a simultaneous side-on and face-on x-ray radiography of the targets has been used in these experiments to observe the process of collision and the evolution of the areal mass amplitude modulation. Its observed evolution is similar to the case of the classical RM instability in finite thickness targets first studied by Y. Aglitsky *et al.*, Phys. Plasmas **13**, 80703 (2006). Our data are favorably compared with 1D and 2D simulation results.

[1]Work supported by the U.S. Department of Energy.

4:24PM PO6.00013 Effects of Preheating on Compression and Rayleigh–Taylor Growth in Planar Plastic Targets on OMEGA

, V.A. SMALYUK, J.A. DELETTREZ, V.N. GONCHAROV, S.X. HU, D.D. MEYERHOFER, S.P. REGAN, T.C. SANGSTER, D. SHVARTS, C. STOECKL, B. YAAKOBI, Laboratory for Laser Energetics, U. of Rochester, J.A. FRENJE, R.D. PETRASSO, PSFC-MIT — Direct-drive inertial confinement fusion ignition target performance is sensitive to the details of thermal coupling, transport, and preheat that directly affect the fuel adiabat. The results of plastic, planar thin-foil acceleration and thick-foil compression experiments on OMEGA at laser intensities from ~2 $\times$ 10^{14} W/cm^2 agree well with 2-D simulations using a constant flux limiter (0.06). However, at intensities of ~1 $\times$ 10^{15} W/cm^2, a nonlocal thermal-transport model or time-dependent flux limiter is necessary to explain the experimental results. In addition, a deposited preheating of ~30 J must be included into simulations at high drive intensities to match the experimental results. The reduction of the Rayleigh–Taylor growth of preimposed modulations at higher intensities correlates with measured hot-electron preheat. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

4:36PM PO6.00014 Validation of Thermal Transport Modeling in Direct-Drive Targets Using PlanarFoil Experiments on OMEGA , S.X. HU, V.A. SMALYUK, V.N. GONCHAROV, P.B. RADHA, J.P. KNAUER, T.C. SANGSTER, D.D. MEYERHOFER, I.V. IGUMENSHCHEV, J.A. MAROZAS, S. SKUPSKY, Laboratory for Laser Energetics, U. of Rochester — Ignition target designs for the direct-drive inertial confinement fusion rely on accurate modeling of thermal transport. Planar-foil OMEGA experiments were used to validate physics models used in 2-D hydrodynamic simulations. The acceleration experiments with 20-μm-thick CH foil were conducted at laser intensities varying from $\sim$2 $\times$ 10^{14} W/cm^2 to $\sim$1 $\times$ 10^{15} W/cm^2. The acceleration was measured using side-on, streaked x-ray radiography. At low laser intensities of $\sim$2 $\times$ 10^{14} W/cm^2, the 2-D simulations with a constant flux limiter of 0.06 agree very well with the experimental measurements, while at high laser intensities up to $\sim$1 $\times$ 10^{15} W/cm^2, a nonlocal thermal transport model or time-dependent flux limiter is necessary to explain experiments. Results of simulations and comparison with the OMEGA experiments will be presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

4:48PM PO6.00015 Laser direct-drive IFE targets: sensitivity to fabrication and drive asymmetries[1] , ANDREW J. SCHMITT, S.T. ZALESAK, J.W. BATES, D.E. FYFE, D.G. COLOMBANT, Naval Research Laboratory, Washington DC — A major challenge for direct-drive inertial fusion energy (IFE) is to create targets that produce significant gain and yet are resistant to the hydrodynamic instabilities that degrade yield. The seeds for these instabilities are the imperfections in both target manufacture and laser illumination. We consider fabrication flaws that occur primarily at surfaces and interfaces, and tend to peak at long wavelengths, although they are appreciable at small scales. Drive non-uniformities include those produced by optical smoothing, beam misalignment and power imbalance. Thus for laser direct-drive, the range of important unstable modes extends over a large wavelength range and to very small amplitudes. Accurate simulation of these modes places severe constraints upon the modeling. We discuss this, and present results using our massively-parallel radiation-hydrocode FAST, which is being used to simulate a variety of different IFE-based targets, including targets with low ignition energy ($E_{laser} \sim 500kJ, G \sim 10-50$), higher energy, high gain targets ($E_{laser} > 1MJ, G > 100$), and shock-ignition designs.

[1]work supported by US DOE

Wednesday, November 14, 2007 2:00PM - 5:00PM –
Session PO7 Turbulence, Reconnection, Phase-Space Holes Rosen Centre Hotel Salon 7/8

2:00PM PO7.00001 Spectra and structure of MHD turbulence[1] , S. BOLDYREV, J.C. PEREZ, University of Wisconsin, Madison, J. MASON, F. CATTANEO, University of Chicago — We present recent results on magnetohydrodynamic (MHD) turbulent cascades. We concentrate on the physical processes that determine the structure of MHD turbulence in the regimes of weak and strong turbulence, and discuss the corresponding turbulent spectra. The results are compared with numerical simulations and geophysical (solar wind) and astrophysical (interstellar scintillation) observations.

[1]Supported by the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas at the University of Wisconsin-Madison and the University of Chicago, and by the U.S. Department of Energy under the grant No. DE-FG02-07ER54932.

2:12PM PO7.00002 Numerical simulations of Alfvénic turbulence in extended reduced MHD , JEAN C. PEREZ, STANISLAV BOLDYREV, University of Wisconsin-Madison — We present the results of numerical investigation of anisotropic Shear-Alfven turbulence in the framework of extended reduced MHD model. The turbulence is randomly stirred at large scales until it reaches a steady state. By properly choosing the forcing parameters we investigate both weak and strong turbulence, and address the question of its transition to the Kinetic-Alfven regime at the ion-sound-radius scale. We observe that the energy spectrum in the weak turbulence regime is flatter than k^{-2} predicted by weak turbulence models.

2:24PM PO7.00003 Numerical Measurements of the Spectrum in Strong Magnetohydrodynamic Turbulence[1] , JOANNE MASON, FAUSTO CATTANEO, University of Chicago, STANISLAV BOLDYREV, University of Wisconsin — We discuss the results of an extensive set of direct numerical simulations of forced, incompressible, strong MHD turbulence with a strong guide field. Our aim is to resolve the controversy regarding the power law exponent of the field perpendicular energy spectrum. The two main theoretical predictions, -3/2 and -5/3, have both received some support from numerical simulations carried out by different groups, however, the design of those calculations also differ. Our simulations have a resolution of 512^3 mesh points, a strong guide field, an anisotropic simulation domain, and implement a broad range of large-scale forcing routines. Our findings indicate that the spectrum of well developed, strong incompressible MHD turbulence with a strong guide field has the exponent -3/2.

[1]This work is funded by the NSF sponsored Center for Magnetic Self-Organization.

2:36PM PO7.00004 Magnetic dynamo action in helical turbulence[1] , LEONID MALYSHKIN, Department of Astronomy & Astrophysics, University of Chicago, STANISLAV BOLDYREV, Department of Physics, University of Wisconsin-Madison, CMSO COLLABORATION — We investigate magnetic field amplification in a turbulent velocity field with nonzero helicity, in the framework of the kinematic Kazantsev-Kraichnan model. We present the numerical solution of the model for the practically important case of Kolmogorov distribution of velocity fluctuations, with a large magnetic Reynolds number. We found that in contrast with the nonhelical case where growing magnetic fields are described by a few bound eigenmodes concentrated inside the inertial interval of the velocity field, in the helical case the number of bound eigenmodes considerably increases, moreover, new unbound eigenmodes appear. Both bound and unbound eigenmodes contribute to the large-scale magnetic field. This indicates a limited applicability of the conventional alpha-model of a large-scale dynamo action, which captures only unbound modes.

[1]Supported by the NSF sponsored Center for Magnetic Self-Organization.

2:48PM PO7.00005 Dissipation of Energy, Cross Helicity, and Magnetic Helicity in Ideal MHD

, HUSSEIN ALUIE, GREGORY L. EYINK, ETHAN T. VISHNIAC, Johns Hopkins University — The "invariants" of ideal MHD–energy, cross helicity, and magnetic helicity–need not be conserved in the limit of zero viscosity and resistivity if the solution fields become singular. This is observed to occur in MHD turbulence, where the effective dissipation is due to nonlinear cascade of the invariants to small-scales. We study the large-scale balances of the three invariants via a "coarse-graining" approach related to Wilson-Kadanoff renormalization group. The ideal dissipation in this framework is due to "turbulent stress" and "turbulent EMF" generated by eliminated plasma motions below the coarse-graining length. We derive upper bounds on these turbulent contributions to the MHD equations and improve the necessary conditions of [1] for ideal dissipation. In particular, we show that the conditions for turbulent dissipation/forward cascade of magnetic helicity are so severe–infinite 3rd-order moments of the velocity & magnetic fields!–that they are unlikely to ever naturally occur. We also establish local balance equations in space-time of the three invariants, both for measurable "coarsed-grained" variables and also for "bare" fields. On this basis we give physical interpretations of the turbulent cascades, in terms of work concepts for energy and in terms of topological linkage [2] for the two helicities. [1] Caflisch et al. 1997 Comm. Math. Phys. 184, 443-455 [2] Moffatt, H. K. 1969 J. Fluid Mech. 35, 117-129.

3:00PM PO7.00006 MHD Turbulence: Generalized Formulation and Extension to Compressible Cases

, BHIMSEN SHIVAMOGGI, University of Central Florida — A general framework that incorporates the Iroshnikov-Kraichnan (IK) and Goldreich-Sridhar (GS) phenomenologies of MHD turbulence is developed. This affords a clarification of the regimes of validity of the IK and GS models. This formulation is generalized further to include compressibility effects.

3:12PM PO7.00007 Condition for Transition to Fast Collisionless Reconnection and its Role in Regulating Solar Coronal Heating[1]

, DMITRI UZDENSKY, Princeton University — I suggest that solar coronal heating is a self-regulating process keeping the plasma marginally collisionless. The proposed mechanism is based on the interplay of two effects. The first one is the transition between the slow collisional (Sweet–Parker) and the fast collisionless reconnection regimes. I formulate a simple criterion for this transition, highlighting the strong effect of the ambient density on gas collisionality. When the density drops below critical, fast reconnection can occur causing magnetic energy release. The second key effect is the chromospheric evaporation caused by the coronal energy release. It increases the density and thereby temporarily inhibits any subsequent reconnection involving a given loop. As a result, statistically, the density fluctuates around a critical value which is found to be comparable with the observed coronal density. On a longer time-scale, coronal heating can be seen as a repeating cycle of fast reconnection events, followed by evaporation episodes, followed by long and quiet periods of magnetic stress build-up and gradual radiative cooling.

[1]Work supported by CMSO.

3:24PM PO7.00008 Evidence for unsteady fast reconnection in a compressible medium[1]

, DONG-WOOK LEE, FAUSTO CATTANEO, University of Chicago, ZORAN MIKIC, Science Applications International Corporation (SAIC), ROBERT ROSNER, Argonne National Lab, ROALD SAGDEEV, University of Maryland, SAMUEL VAINSHTEIN, University of Chicago — We present numerical evidence based on 2.5-dimensional simulations with constant classical resistivity of unsteady reconnection in a compressible medium. The initial configuration consists of a magnetic arcade with a nonzero longitudinal field embedded in a background stratified corona. In the strong compressibility regime the reconnection speed is observed to exceed the Sweet-Parker rate. The crucial ingredient that leads to the fast reconnection rate is the compressive collapse of the current sheet driven by the efficient diffusion of the longitudinal field. The calculation were carried out in a regime in which gravity was dominant in the sense that $F = gl\Big/(C_A C_S) >> 1$ where g is the gravitational acceleration, l is the magnetic scale, and C_A and C_S are the Alfvén and sound speeds respectively. Although the present model is not applicable to the solar case, it describes stars with stronger surface gravity.

[1]The University of Chicago FLASH Center.

3:36PM PO7.00009 Ohm's Law in 3D turbulent magnetic Reconnection[1]

, HAIHONG CHE, J. DRAKE, M. SWISDAK, University of Maryland — The evolution of kinetic instabilities and their role in fast magnetic reconnection are long-standing puzzles. In this paper we investigate these two issues by studying the role of Buneman instability in the electron diffusion region of collisionless magnetic reconnection. We obtain a second-order approximation of the first moment of Vlasov equation for evolving kinetic instabilities in which non-linear wave-particle interactions dominate. The resulting Ohm's law shows two new important characteristics: the drag force and turbulence viscosity. Using particle-in-cell simulations we study the evolution of this new Ohm's law. We perform 2D and 3D simulations with a strong guide field for both low and high initial electron temperatures. In the high temperature 3D simulation turbulence around x-line is absent. In the low temperatures 3D simulation the Buneman instability develops and evolves into a state with strong turbulence. Our simulations show that the turbulence effects can support fast reconnection: 1) The turbulence-induced drag force and viscosity are important factors in supporting the reconnection electric field at the late stages of reconnection; 2) Turbulence heating enhances the role of non-gyrotropic pressure and weakens the role of electron inertia in supporting the reconnection electric field.

[1]NASA and NSF.

3:48PM PO7.00010 Merging Spheromak as Axisymmetric Plasma Equilibrium with Flow

, JANG-YU HSU, Department of Physics and Plasma and Space Science Center, NCKU, Tainan, Taiwan, CHANGMO RYU, Department of Physics, Postech, Pohang 790-784, Korea — It was reported that merging two spheromaks with opposite toroidal magnetic fields does not always lead to another spheromak, but may relax to a Field Reversed Configuration (FRC) with a high-β value when the initial magnetic helicity is below certain critical value. The high-β FRC rules out the relaxation to the force-free Taylor state. The plasma is self-organized under other invariant than the magnetic helicity. It was shown by Montgomery et. al. that maximizing the entropy for the given total current leads to the canonical profile. Hsu et. al. applied successfully the total current constraint to describe the tokamak plasma relaxation to bifurcated equilibrium solutions. The current conservation seems likely during the annihilation process of equal but opposite currents of merging spheromaks. In this paper, we show that a poloidal flow faster than the poloidal Alfven velocity provides a high-β plasma equilibrium. As the toroidal current is annihilated and the poloidal Alfven velocity is vanishingly small, it goes to the hydrodynamic limit.

4:00PM PO7.00011 Nonlinear Dynamics of Fluctuations in the Presence of Sheared Flows in a Magnetized Laboratory Plasma[1]

, M. GILMORE, L. YAN, S. XIE, C. WATTS, University of New Mexico — Velocity shear is known to play an important role in the stability threshold of drift modes, as well as the suppression of drift turbulence, in both fusion and space plasmas. In addition, shear can destabilize modes such as Kelvin-Helmholtz (K-H). A set of laboratory experiments is described which utilize a set of concentric bias rings to affect the velocity (flow) shear in a linear device. With increasing ring bias, relative to the vacuum chamber wall, it is found that both axial and azimuthal flow shear change by only a small amount in magnitude, but move inward to the plasma core from the wall. As bias is increased, drift waves decrease in magnitude and are eventually fully suppressed, then the K-H mode is destabilized. While bias applied to rings at any radii suppresses drift fluctuations with nearly equal effectiveness, the K-H mode is more easily excited by biasing at the plasma edge. Fluctuations show increasingly chaotic and intermittent behavior as bias increases, up to V $\sim$ 10kTe/e, when the chaos disappears, as indicated by a rapid drop in correlation dimension. Experimental results and comparisons with theory are described.

[1]Work supported by U.S. DoE grants no. DE-FG02-04ER54791 and DE-FG02-06ER54898

4:12PM PO7.00012 Turbulent transport in drift wave turbulence: the role of coherent vorticity[1]

, WOUTER BOS, MSNM-CNRS & CMI Université de Provence, France, SHINPEI FUTATANI, Graduate School of Energy Science, Kyoto University, Japan, KAI SCHNEIDER, MSNM-CNRS & CMI Université de Provence, France, MARIE FARGE, LMD-CNRS, Ecole Normale Supérieure, Paris, France, SADRUDDIN BENKADDA, PIIM-CNRS, Université de Provence, France — A wavelet based technique for extracting coherent vortices, called coherent vortex extraction, is applied to simulations of drift wave turbulence. We show that the coherent vorticity, represented by few degrees of freedom, is responsible for the dynamics and transport. The radial density flux is carried by these coherent vorticity modes. The quasi-hydrodynamic limit shows a local depletion of nonlinearity and can be quantitatively distinguished from the quasi-adiabatic case by the skewness of the probability distribution function of the Weiss-field.

[1]We thankfully acknowledge financial support from the ANR, contract M2TFP.

4:24PM PO7.00013 A field theoretical model of self-organization of the vorticity field in two-dimensional plasma and in planetary atmosphere

, FLORIN SPINEANU, MADALINA OLIMPIA VLAD, NILPRP — Starting from plasma/fluids models of interacting point-like vortices we develop a field theoretical description for the 2D Euler fluid (non-dissipative incompressible fluids) and for the 2D plasma in strong magnetic field (Hasegawa-Mima) and planetary atmosphere (Charney) fluids. We find the Lagrangian densities and action functionals, and derive the equations of motion. We prove that between the states that attain the extrema of the action there is a subset of stationary states that correspond to absolute minima and are reached by the system asymptotically. We show that they are respectively described by the sinh-Poisson equation (confirming by purely analytical means a previous result) and by a new equation for 2D plasma and atmosphere. Solving numerically the second equation we show that it reproduces large scale 2D flows in tokamak plasma. We argue that the states of high confinement are connected with states of organization of plasma vorticity.

4:36PM PO7.00014 What Can We Learn About Electron Distributions From Measurements of Weak Bipolar Fields?*

, MARTIN V. GOLDMAN, DAVID L. NEWMAN, University of Colorado, ANDRÉ MANGENEY, Observatoire de Meudon, Paris, France — A given bipolar field that is stationary in a co-moving frame can correspond either to an ion soliton or an electron phase-space hole. In the limit of weak potential, ϕ, with $e\phi_{\max}/T_e \ll 1$, either of these structures can have the asymptotic shape $\phi = \phi_{\max}\mathrm{sech}^4(x/\alpha)$. For ion solitons, the half width ($\propto \alpha$) depends on $\phi_{\max}$, whereas for electron holes the half-width is independent of $\phi_{\max}$. We show analytically for holes in this limit that $\phi_{\max}$ depends on the (finite) energy derivative of the trapped distribution at the separatrix, while α depends only on a "screening" integral over the untrapped distribution. Idealized trapped and passing electron distributions are shown to be *inferrable* from the speed, amplitude, and shape of weak bipolar waveform measurements. For measurements[1] of hundreds of weak bipolar field events in Earth's cusp, the theory is shown to be consistent with the most frequently observed *half-width* between bipolar field peaks, and with various other features of the measured[1] distribution of hole velocities vs hole half-widths.

* Work supported by NSF, NASA, and DOE, and submitted in part to *Phys. Rev. Lett.* as "Theory of Weak Bipolar Fields and Electron Holes with Space Applications," (2007).

[1] Franz, J.R., *et al.*, *J. Geophys. Res.* **110**, A09212, 2005.

4:48PM PO7.00015 New Route to Shallow Electron Phase-Space Holes via a "Velocity-Notch" Instability*

, DAVID L. NEWMAN, MARTIN V. GOLDMAN, University of Colorado — Properties of weak bipolar fields observed in space are found to be consistent with a theory for shallow electron phase space holes.[1] Here, we show that shallow phase space holes can develop *dynamically* as a result of trapping during the saturation of a new electron "velocity-notch" instability. This instability occurs when there is a "notch" of width Δv and density deficit Δn in a unimodal electron velocity distribution with density n_{e0} and thermal speed v_{e0}, provided $\Delta v/v_{e0}$ is sufficiently smaller than $\sqrt{\Delta n/n_{e0}}$. In the narrow-notch limit, the growth rate is the *plasma frequency of the missing notch electrons*. The nonlinear saturation of this instability is studied using Vlasov simulations initiated with two different classes of electron distributions: Spatially uniform electron distributions with a shallow velocity notch result in holes whose form depends on the degree to which the instability threshold is exceeded. Distributions initialized with a *spatially local* temperature enhancement develop a notch in velocity due to time-of-flight effects. This notch becomes progressively narrower until the instability threshold is crossed. The bipolar fields in the simulations are compared with those corresponding to the weak potential solutions $\phi = \phi_{\max}\mathrm{sech}^4(x/\alpha)$ from theory.[1]

* Work supported by NSF, NASA, and DOE

[1] M. V. Goldman, *et al.*, this meeting.

2:00PM - 2:00PM –

Session PP8 Poster Session VI: Shocks, Flows, Dusty and Complex Plasmas; Z Pinches, X Pinches, EOS, and HEDP; Stellarator; FRCs, Flow Pinch, HBT-EP, Helimak and LDX

Rosen Centre Hotel Grand Ballroom, 2:00pm - 5:00pm

PP8.00001 SHOCKS, FLOWS, DUSTY AND COMPLEX PLASMAS –

PP8.00002 Heating and cooling in dusty plasmas[1]

, Y. FENG, J. GOREE, BIN LIU, Dept. of Physics and Astronomy, The Univ. of Iowa — A dusty plasma is a partially ionized gas containing small particles of solid matter, which are typically micron size. These particles gain a large electric charge by collecting electrons and ions from the ambient plasma, so that they interact with a large potential energy, yielding a strongly-coupled plasma. Particles can thereby organize in a crystal, which in our experiment is a single layer of microspheres. We can melt this crystal to form a liquid by heating it with random kicks from moving laser beams. The laser imparts a radiation-pressure force on the particles, which also experience frictional drag simultaneously by gas atoms. At steady state, a balance of laser heating and gas cooling determines a temperature. Results will be reported for an experiment where we disturb this balance with a sudden change in heating power to study the temporal development of melting and freezing.

[1]Supported by DOE and NASA

PP8.00003 Dispersion relation of Dust-acoustic waves in three-dimensional complex plasmas under microgravity , SILVIA V. ANNIBALDI, Space-and Plasma Physics, EE, KTH, SE-10044 Stockholm, Sweden, A.V. IVLEV, U. KONOPKA, Max-Plank-Institut fur Extraterrestrische Physik, D-85741 Garching, Germany, S. RATYNSKAIA, Space-and Plasma Physics, EE, KTH, SE-10044 Stockholm, Sweden, H. THOMAS, G. MORFILL, Max-Plank-Institut fur Extraterrestrische Physik, D-85741 Garching, Germany, A. LIPAEV, V. MOLOTKOV, O. PETROV, V. FORTOV, Institute for High Energy Density, RAS, 125412 Moscow, Russia, J. DRAKE, Alfven Laboratory, EE, KTH , SE-10044 Stockholm, Sweden — In order to measure the dispersion relation for longitudinal Dust-acoustic (DA) waves in quasi-isotropic 3D complex (dusty) plasmas, a series of dedicated experiments with the PKE-Nefedov [1] setup were performed on board the International Space Station. The waves were excited by applying ac electric modulation of variable frequency to the rf electrodes. The amplitude of excitation was varying with frequency to ensure "sufficiently linear" regime of the dust density perturbations. The dispersion relation was obtained by measuring the induced density perturbations, revealing fairly good agreement with a simple multispecies theory of DA waves [2]. [1] Nefedov A P et al, 2003, New. J. Phys., vol. 5, 33.1. [2] Rao N N et al, 1990, Planet. Space Sci., vol. 38, 543.

PP8.00004 Dust Impact Studies in Regard to Dust/Wall Interactions in Fusion Research , JAMES CREEL, JORGE CARMONA-REYES, MIKE COOK, JIMMY SCHMOKE, TRUELL HYDE, CASPER - Baylor University — Particulate contamination has long been an area of concern within the fusion community. Past research has focused primarily on decreasing dust production as well as placing limits on overall dust retention. Unfortunately, due to the increased surface area and higher operating temperatures proposed for ITER, it is assumed that dust production within this environment will be particularly pronounced. The dynamics (and the underlying physics) for dust particles within such an environment are not yet well understood, particularly the manner in which dust interactions occur with the wall. We will discuss an experimental technique, which applying dust and wall parameters from current fusion devices, provides experimental impact data utilizing a single stage light gas gun. The resulting data will be used to discuss dust production methods, dust accretion on the walls, and dust/wall durability.

PP8.00005 Complex Plasma Studies on Ferromagnetic Dust , JORGE CARMONA, MATTHEW BENESH, CHELSEA CHAN, JIMMY SCHMOKE, MICHAEL COOK, TRUELL HYDE, CASPER Baylor University — Dust particles imbedded within plasma are charged through collisions with free electrons and ions. If the ratio of the inter-particle potential energy to the average kinetic energy is sufficient, the particles form disordered or ordered structures depending on whether short or long range ordering dominates. For dust particles forming crystalline structures residing within two-dimensionally extended lattice planes, various stable crystalline phases have been observed experimentally. The dynamics of this behavior is driven in large part by the charge on the particle. Although the charging process for insulating materials has been examined in detail, conducting materials have not yet been fully investigated. This study presents data for 4.5 μm ferromagnetic dust examined under several pressure and power conditions within a standard GEC reference cell.

PP8.00006 Sensitivity Analysis on Boundary Conditions for Continuum Regime Probe , H.L. RAPPAPORT, Enig Associates — In both classic literature on the continuum regime Langmuir probe [1], and recent literature on dust grain charging [2], the assumption is made that the electron and ion densities vanish on the probe surface. This implies a singularity in the respective fluid velocities at the surface under steady state conditions. Our recent kinetic simulations [3] of electrons near the surface of a planar probe, showed that reasonable electron boundary conditions require the electron density at the probe surface be on the order of the equilibrium density times the ratio of the electron drift velocity over the thermal speed. Density does not vanish, nor does temperature remain constant, as the surface is approached. In this poster, a sensitivity analysis on spherical probe current and potential is performed to investigate how changes in electron and ion boundary conditions affect results.

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2) S.A. Khrapak, G.E.Morfill, A.G. Khrapak, L.G. D'yachkov, Phys. Plasmas, Vol. 13, No. 5, 2006.
3) H.L. Rappaport, presented at APS/DPP 2006.

PP8.00007 Complex Plasma with Multiple Distinct Particle Sizes , BERNARD SMITH, TRUELL HYDE, MIKE COOK, JIMMY SCHMOKE, CASPER - Baylor University — Dust particle clouds can be found in most fusion and almost all plasma processing environments including both plasma-etching devices and in plasma deposition processes. Dust particles suspended within such plasmas acquire an electric charge from collisions with free electrons in the plasma. If the ratio of the inter-particle potential energy to the average kinetic energy is sufficient, the particles can form either a "liquid" structure with short range ordering or a crystalline structure with longer range ordering. The preponderance of experiments to date have employed monodisperse spheres to form the complex plasma system. In contrast, this paper examines the effect that a size distribution will have on overall particle ordering. Two dimensional (2D) plasma crystals were formed employing mixtures of 8.89 μm, 6.50 μm, and 4.57 μm monodisperse particles in Argon plasma. The pair correlation function was determined at differing pressures and powers and then compared to corresponding measurements obtained for monodisperse spheres alone and vibrational data was examined to determine specific dust and plasma parameters. Multiple experiments were conducted to investigate the manner in which system phase transitions and other thermodynamic properties depend upon the overall dust grain size distribution.

PP8.00008 Dispersion relation for the dust-acoustic wave in a Lorentzian plasma[1] , MYOUNG-JAE LEE, TAEJOON KIM, Department of Physics, Hanyang University, Seoul, Korea, KYU-SUN CHUNG, HYUN-JONG WOO, Department of Electrical Engineering, Hanyang University, Seoul, Korea — The electrostatic mode of dust-acoustic (DA) surface waves propagating on the interface between a vacuum and a complex plasma is kinetically investigated by using the dispersion relation based on the Vlasov-Maxwell equations. The complex plasma consists of Lorentzian (kappa) electrons and ions, and cold dusty particles. The results show that in the long wavelength limit ($k_x\lambda_D \to 0$), the frequency of the wave is reduced to $\omega \approx (\mu_\kappa)^{1/2} k_x C_D$ where μ_κ is a kappa (spectral index) dependent factor and $C_D = \omega_{pd}\lambda_D$ is the well known dust acoustic speed. We see that the frequency increases as the ratio of dust density to ion density increases. Some interesting results of the DA surface waves supported by the Lorentzian plasma are discussed.

[1]This work was supported in part by the 2nd stage Brain Korea 21 Program and in part by the National Research Laboratory (NRL) Program of Korea Science and Engineering Foundation (KOSEF) under the Korean Ministry of Science and Technology.

PP8.00009 Dispersion properties of the dust-acoustic waves in a Lorentzian plasma containing elongated dust grains.[1] , TAEJOON KIM, MYOUNG-JAE LEE, Department of Physics, Hanyang University, Seoul, Korea, KYU-SUN CHUNG, Department of Electrical Engineering, Hanyang University, Seoul, Korea — The dispersion relation for electrostatic waves propagating in an unmagnetized dusty plasma whose constituents are electrons, ions, and elongated charged dust grains is obtained and analyzed. Electrons and ions are assumed to be Lorentzian (kappa velocity distribution) and dust grains are assumed to be cold. We consider the one-dimensional dust grain rotation so that the principal moment of inertia has z-component only. In the limit of low frequency, i.e., $\omega << kv_e$, kv_i, the dust acoustic (DA) wave dispersion relation is kinetically derived by employing Poisson-Maxwell equations. The result shows that the dispersion relation can admit complex solutions and the growth rate is proportional to the rotation frequency. The effects of spectral index κ are also discussed.

[1]This work was supported in part by the 2nd stage Brain Korea 21 Program and in part by the National Research Laboratory (NRL) Program of Korea Science and Engineering Foundation (KOSEF) under the Korean Ministry of Science and Technology.

PP8.00010 Oblique dust density waves[1] , ALEXANDER PIEL, OLIVER ARP, KRISTOFFER MENZEL, MARKUS KLINDWORTH, Christian-Albrechts-Universitaet Kiel — We report on experimental observations of dust density waves in a complex (dusty) plasma under microgravity. The plasma is produced in a radio-frequency parallel-plate discharge (argon, $p = 15$Pa, $U = 65\text{V}_{pp}$). Different sizes of dust particles were used (3.4 μm and 6.4μm diameter). The low-frequency ($f \approx 11$Hz) dust density waves are naturally unstable modes, which are driven by the ion flow in the plasma. Surprisingly, the wave propagation direction is aligned with the ion flow direction in the bulk plasma but becomes oblique at the boundary of the dust cloud with an inclination of $\approx 60^\circ$ with respect to the plasma boundary. The experimental results are compared with a kinetic model in the electrostatic approximation [1] and a fluid model [2]. Moreover, the role of dust surface waves is discussed.
[1] M. Rosenberg, J. Vac. Sci. Technol. A 14, 631 (1996)
[2] A. Piel et al, Phys. Rev. Lett. 97, 205009 (2006)

[1]Supported by DLR grant 50WM0339 and DFG grant TR-24 A2.

PP8.00011 Observations of dust acoustic waves driven at high frequencies[1] , ROSS FISHER, ROBERT MERLINO, University of Iowa, EDWARD THOMAS, Auburn University — Previous measurements of the dispersion relation of dust acoustic waves (DAW) have been restricted to frequencies less than 35 Hz. We report new measurements of the DAW dispersion relation with driving frequencies up to 200 Hz. The experiments were performed in a dusty plasma produced in a argon DC glow discharge. Although DAWs are spontaneously excited in the dusty plasma, a sinusoidal modulation of the discharge current allows the DAW to be synchronized at the applied driving frequency. For each driving frequency, the average wavelengths of the DAW were determined by recording video images of the scattered light intensity. A comparison of the measured dispersion relation with the theoretical DAW dispersion relation indicates that finite dust temperature effects must be taken into account. A new interesting feature revealed in the experiment is the modulation of the 'naturally' excited DAW by the high frequency driven DAW, which appears as a fine structure in the video images of the waves.

[1]Work supported by DOE Grant DE-FG02-04ER54795 (UI) and NSF Grant PHY-0354938 (AU)

PP8.00012 Vertically propagating driven dust acoustic waves in a dc glow discharge dusty plasma[1] , E. THOMAS, J. WILLIAMS, L. MARCUS, Auburn University, R. MERLINO, University of Iowa — Early experimental and theoretical studies of these dust acoustic waves (DAW) have generally assumed that the kinetic dust temperature is comparable to that of the background ions and, as a result, finite dust temperature effects were not considered to play a significant role. However, a number of studies [e.g., J. Williams, et al., Phys. Plasmas, 14, 063702 (2007)] suggest that the kinetic dust temperature may be as high as tens of electron volts. This experimental study, in combination with work by Fisher, et al. (this session), shows that finite dust temperature effects modify the dust dispersion relation. In this study, monodisperse 1.51-micron diameter, silica microspheres are used to form a dusty plasma in an unmagnetized, argon dc glow discharge. Vertically propagating, driven DAW's are formed by modulating the current applied to the anode. Results will be presented on measurements of the dispersion relation and measurements of zero- and first-order wave components obtained using stereo-PIV techniques.

[1]This work is supported by NSF Grant PHY-0354938 (AU) and DOE Grant DE-FG02-04ER54795 (UI)

PP8.00013 Preliminary measurement of ion heating in a weakly-coupled complex (dusty) plasma , JEREMIAH WILLIAMS, Wittenberg University, EDWARD THOMAS, LYDIA MARCUS, Auburn University — In previous [J. Williams, et al., Phys. Plasmas, 14, 063702 (2007)] and ongoing [Thomas, et al. and Merlino, et al. (this session)] experimental studies, it has been observed that the kinetic temperature of the microparticle component of a weakly-coupled complex (dusty) plasma, CDP, is significantly larger than the other plasma components (electrons, ions and background neutrals), a result that is consistent with previous measurements of the kinetic temperature for a plasma crystal in a fluid-like state. While there are no direct theoretical predictions to explain the mechanism responsible for heating the microparticle component to the observed temperatures in a weakly-coupled CDP, there have been a number of mechanism proposed to explain the observations involving the plasma crystal. Among the most promising of these mechanisms is an instability triggered by ions streaming past the dust particles. In this presentation, we present preliminary experimental results examining the possible role played by the ions in heating the microparticle component of a weakly-coupled CDP. This work is supported by NSF Grant PHY-0354938.

PP8.00014 Floating potential and collisionless ion drag force on a spherical grain under weakly magnetized conditions , LEONARDO PATACCHINI, IAN H. HUTCHINSON, MIT — The interaction of a spherical object with a collisionless plasma under weakly magnetized conditions is investigated by means of the PIC code SCEPTIC [1]. The key features of this 2D3v electrostatic ion kinetic code are a spherical geometry accurately resolving the collector's edge, and a Boltzmann treatment of the electrons, whose current is calculated using a recently developed empirical formula accounting for their magnetization [2]. By asymmetrically reducing the ion and electron fluxes to the collector, the magnetic field ($\mathbf{B}$) has a strong influence on the floating potential (ϕ_f). The non monotonic dependence of ϕ_f on $\mathbf{B}$ is documented for a wide range of plasma parameters relevant to probes and dust particles. The magnetic field is also shown to reduce the ion focusing effects present in an unmagnetized plasma when the drift velocity is non negligible, thus the electrostatic part of the ion drag force. This effect is compared with the variation of the electron-ion Coulomb collision frequency with the local magnetic field.
[1] I.H. Hutchinson PPCF 47, 71-87 (2005)
[2] L. Patacchini et al. Phys. Plasma 14, 062111 (2007)

PP8.00015 Observation of melting in a heated, two-dimensional complex plasma[1] , T.E. SHERIDAN, Department of Physics & Astronomy, Ohio Northern University — The melting transition in a two-dimensional complex plasma has been studied experimentally. The complex plasma is heated by amplitude modulating the rf discharge power with a square wave at the vertical resonance frequency. The vertical motion couples to an in-plane dust-acoustic instability at one-half the driving frequency, thereby increasing the average in-plane kinetic energy (i.e., the effective "temperature") of the system. The "thermodynamic" phase of a complex plasma consisting of $\approx 3900\ 9-\mu$m diameter particles has been characterized for increasing levels of amplitude modulation at constant neutral pressure (35 mtorr Ar) and constant average rf power using the bond-orientational correlation function, defect densities, the Lindemann ratio and the pair correlation function. A melting transition showing clear evidence for hexatic and liquid phases is observed.

[1]Supported by an O. N. U. Undergraduate Faculty Development Grant

PP8.00016 Ionosphere Dusty Plasma in the Laboratory , SCOTT ROBERTSON, Univ. Colorado, GREGOR BANO, WARD HANDLEY, MIHALY HORANYI, ZOLTAN STERNOVSKY — We describe an experiment that creates dusty plasma with nanometer-sized particles that is similar to the ionosphere in which there are "smoke" particles from the ablation of meteors. The meteoritic smoke layer is global and extends from about 70-100 km. The smoke particles are thought to be the condensation nuclei for noctilucent clouds. The meteoritic particles descend into the polar stratosphere in the winter. A Zn vapor source is used to create a smoky gas of Zn particles that are up to tens of nanometers in size and these are seen both by laser scattering and by collecting them on a substrate viewed by electron microscope. A differential pumping scheme is used to introduce the particles into a hot-filament discharge plasma. Probe methods are used to search for charged nanometer-sized particles in decaying afterglow plasma.

PP8.00017 Theoretical and experimental studies of dust particle charging in the presence of a magnetic field[1] , CHRIS FICHTL, GIAN LUCA DELZANNO, Los Alamos National Lab, SU-HYUN KIM, ROBERT MERLINO, University of Iowa, GIOVANNI LAPENTA, KU-Leuven — The physical process of the charging of a dust particle immersed in a plasma with an applied background magnetic field is studied theoretically and experimentally. The theoretical study is conducted by means of a spherical harmonics expansion of the Maxwell-Boltzmann equations. Furthermore, we perform PIC simulations of a single particle immersed in a plasma subject to static background magnetic fields of various magnitudes to obtain characteristic charging curves. From this point, various detailed physics packages are added to the PIC code for more accurate simulations. Experiments are being planned in which single micron-size dust particles are dropped into a magnetized Q machine plasma where they become charged and subsequently fall into a Faraday cup where their charge is measured. Charge measurements will be performed at different values of the magnetic field.

[1]Work at UI is supported by DOE

PP8.00018 0-D and 2-D LIF Measurements of Small Coulomb Crystals in a Linear RF Trap[1] , MITSUTOSHI ARAMAKI, AKIHIRO KONO, Nagoya University, Japan — One goal of our ion trap experiment is to clarify the mesoscopic statistical properties of small one-component plasmas. As the beginning phase of the research, we improved the controllability of laser-cooled one-component plasmas, and developed 0-D and 2-D LIF measurement system. Since the temperature of laser-cooled ions is sensitive to the wavelength of the cooling laser in the vicinity of the phase transition, the stabilization of the laser system is necessary to perform systematic experiments. In this experiment, the long-term drift of the laser wavelength was suppressed to several mega hertz or less per 10 minutes by locking to a Fabry-Perot interferometer. 0-D and 2-D LIF measurements were performed using a photomultiplier or an ICCD camera, respectively. Commonly, it is believed that the sudden drop of 0-D LIF signal indicates the crystallization of plasma. However, the 2-D LIF image immediately after the sudden drop of the 0-D LIF signal showed a cloudy image. In this presentation, we will show the detail of the difference between the 0-D and 2-D LIF results.

[1]This research was supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (C), 19540519, 2007

PP8.00019 Crystallization in mass and charge asymmetric bilayers[1] , MICHAEL BONITZ, PATRICK LUDWIG, ALEXEI FILINOV, Institute for Theoretical Physics and Astrophysics, Kiel University, Germany, YURII LOZOVIK, Institute of Spectroscopy, Russian Acad Sciences, Troitsk, Russia, HEINRICH STOLZ, Inst Physics, Rostock University, Germany — We consider Coulomb crystal formation in quantum electron-ion (hole) bilayers. Varying the mass ratio M of ions and electrons between 1 and 100 for a fixed layer separation d at low temperature and high density, one can tune the hole behavior from delocalized (quantum) to localized (quasi-classical) while the electrons remain delocalized all the time. While in 3D plasmas [1], ions crystallize if the mass ratio exceeds a critical value of $M_{cr} \sim 80$, in bilayers M_{cr} can be drastically reduced by properly choosing d and the in-layer particle density. The complicated overlap of correlation and quantum effects of both, electrons and holes, is fully taken care of by performing first-principle path integral Monte Carlo simulations.
[1] M. Bonitz, V.S. Filinov, V.E. Fortov. P.R. Levashov, and H. Fehske, Phys. Rev. Lett. 95, 235006 (2005) and J. Phys. A: Math. Gen. **39**, 4717 (2006). [2] P. Ludwig, A. Filinov, Yu. Lozovik, H. Stolz, and M. Bonitz, Crystallization in mass-asymmetric electron-hole bilayers, Contrib. Plasma Phys. (2007), ArXiv: cond-mat/0611556

[1]Supported by the Deutsche Forschungsgemeinschaft via SFB-TR 24.

PP8.00020 Breathing Mode in Complex Plasmas[1] , K. FUJIOKA, City College of New York, C. HENNING, P. LUDWIG, M. BONITZ, ITAP, Christian-Albrechts-Universitaet zu Kiel, A. MELZER, Institute of Physics, Greifswald University, S. VITKALOV, City College of New York — The breathing mode is a fundamental normal mode present in Coulomb systems, and may have utility in identifying particle charge and the Debye length of certain systems. The question remains whether this mode can be extended to strongly coupled Yukawa balls [1]. These systems are characterized by particles confined within a parabolic potential well and interacting through a shielded Coulomb potential [2,3]. The breathing modes for a variety of systems in 1, 2, and 3 dimensions are computed by solving the eigenvalue problem given by the dynamical (Hesse) matrix. These results are compared to theoretical investigations that assume a strict definition for a breathing mode within the system, and an analysis is made of the most fitting model to utilize in the study of particular systems of complex plasmas [1,4].
References
[1] T.E. Sheridan, Phys. of Plasmas. 13, 022106 (2006)
[2] C. Henning et al., Phys. Rev. E 74, 056403 (2006)
[3] M. Bonitz et al., Phys. Rev. Lett. 96, 075001 (2006)
[4] C. Henning et al., submitted for publication

[1]Supported by the DFG (via SFB-TR24) and the DAAD RISE Program

PP8.00021 Measurement of emission from a radiatively collapsed shock , A. VISCO, R.P. DRAKE, M.J. GROSSKOPF, N. GJECI, R.S. GILLESPIE, J.D. SHULTZ, D.A. CAMPBELL, J. HUMAN, University of Michigan — Radiatively collapsed shocks are systems in which radiation transport causes the shock to "collapse" or compress to high densities. Such shocks are present in supernova remnants, passing through interstellar medium, and other such astrophysical systems. With the advent of large laser facilities, conditions can be created so that radiativly collapsed shocks can be studied in quantitative way. Recent experiments have been preformed on the Omega laser at the Laboratory for Laser Energetics to study the dynamics of these shocks. Measurements of radiative emission from the collapsed shock and precursor region have been made using a streaked optical pyrometer from which the temperature of the system can be calculated. Details of the experiment and results will be discussed. This research was sponsored by the NNSA through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA00064, and other grants and contracts.

PP8.00022 Plasma Formation on an Aluminum Surface Driven by MG Fields[1] , STEPHAN FUELLING, BRUNO BAUER, RICHARD SIEMON, TOM AWE, VOLODYMYR MAKHIN, TASHA GOODRICH, ANDREW OXNER, RADU PRESURA, University of Nevada, Reno — Experiments on the UNR 1 MA Zebra generator drive magnetic fields of several megagauss on the surface of an aluminum conductor. This physics is important in a number of applications including magnetized target fusion. Several 1-mm diameter load designs were tested. The rod diameter was larger than the skin depth for the 70-ns current rise. Diagnostics included optical imaging to a time-gated intensified CCD camera and a streak camera, magnetic field probes, photodiodes, photomultipliers, and laser shadowgraphy, schlieren, and interferometry. These yielded information on the threshold for plasma formation, the expansion of the aluminum, the temperature at the surface, and the growth of the unstable m=0 mode driven by the curvature of the magnetic field. Time-gated images show markedly more uniform light from machined loads than from wire loads. The relatively simple experimental setup was chosen to allow comparison with 1-D and 2-D rad-MHD modeling.

[1]Work supported by DOE grants DE-FG02-04ER54752, DEFG02- 06ER54892, and DE-FC52-01NV14050.

PP8.00023 Numerical Modeling of Megagauss Fields on Aluminum Rods , VOLODYMYR MAKHIN, THOMAS AWE, BRUNO BAUER, University of Nevada, Reno, IRVIN LINDEMUTH, RICHARD SIEMON, University of Nevada, Reno, WALT ATCHISON, THOMAS TIERNEY, Los Alamos National Laboratory, MICHAEL FRESE, SHERRY FRESE, NumerEx, MICHAEL DESJARLAIS, THOMAS HAILL, Sandia National Laboratory, RICKEY FAEHL, Allyson Faehl, Inc., SERGEY GARANIN, VNIIEF — Metal plasma formation and stability were studied on the surface of aluminum rod in recent experiments driven by the UNR Zebra generator [1]. The surface response to megagauss fields is important for a number of applications, including Magnetized Target Fusion (MTF). Recent radiation-hydro numerical simulations by Garanin et al. show how plasma can be generated on a metal surface [2]. Numerical simulations with codes used at UNR (MHRDR and RAVEN), and codes from other institutions, show luminosity, radial expansion, and plasma formation or lack thereof that can be compared with experimental data. The sensitivity of modeling to various equation-of-state and resistivity models will be discussed.

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[2] S.F. Garanin et al., J. Appl. Mech. Tech. Phys. 46, 153(2005).

PP8.00024 Interaction of laser-produced plasmas with large magnetoplasmas , CHRISTOPH NIEMANN, CARMEN CONSTANTIN, ANDREW COLLETTE, SHREEKRISHNA TRIPATHI, PATRICK PRIBYL, ERIK EVERSON, ALEXANDRE GIGLIOTTI, STEPHEN VINCENA, UCLA, RADU PRESURA, STEPHAN NEFF, CHRISTOPHER PLECHATY, UNR, WALTER GEKELMAN, UCLA — We will present experiments on the interaction of dense laser-produced plasmas with a large mangetoplasma. A high-energy laser (>20 J) coupled to the Large Plasma Device (LAPD) at UCLA allows unique experiments on laser driven shocks that can approach the collisionless regime. Focused laser intensities around 10^{13} W/cm^2 produce an ablating plasma-plume with expansion velocities of several 100 km/s. Prior to the laser pulse an ambient plasma with a size of 18 m lengths and 50 cm diameter at $4x10^{12}$ cm^{-3} and T$_e$=5 eV is created in an axial magnetic field of 600-1800 G. We will present measurements of Alfven waves radiated from the laser-produced plasma, as well as a characterization of the evolution and particle distribution of the laser-produced plasma 'piston'.

PP8.00025 Observation of Thermal Effects for Shock Wave Acceleration in Glow Discharge Plasma[1] , NIRMOL K. PODDER, ANASTASIA V. TARASOVA, RALPH B. WILSON IV, Troy University, Troy, AL — Shock waves launched into weakly-ionized plasmas experiences an increased velocity and dispersion. These effects have been primarily attributed to: (i) gas temperature gradient and thermal effects, and (ii) plasma-specific (electron density, temperature, and electric field) effects. In this work, we investigate the thermal effects on the observed shock wave modifications in plasma. At a fixed Mach number, shock waves are launched with an incremental delay from the switch-on of the discharge. It is found that the shock wave velocity in plasma increases as the delay is increased, and reaches a steady-state value at a delay of about 100 ms.

[1]This work is supported by the DOE.

PP8.00026 Self similar nonlocal electron heat flow , JEAN-PIERRE MATTE, INRS-EMT, Un. du Quebec — The well known self similar heat diffusion solutions of Zel'dovich and Raizer [1], for a heat wave advancing from a boundary at a fixed temperature or a fixed heat flux do not keep the ratio R of the scale length to the mean free path constant. Instead, R increases and the solution becomes increasingly valid because Spitzer-Harm [2] heat flow is increasingly applicable. A self similar solution exists which keeps R constant, if one assumes that the boundary heat flux increases in time. Similarly, for the problem of a uniform density plasma heated by a finite width laser beam, a self similar solution keeping R constant can be obtained by assuming that the beam intensity and width increase in time. Such solutions will be studied with the electron kinetic code FPI [3], and compared to simulations with more usual laser characteristics.

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[2] L. Spitzer and R. Harm, Phys. Rev. **89**, 977 (1953).
[3] J.-P. Matte *et al.*, Phys. Rev. Lett. **53**, 1461 (1984) ; *ibid* **49**, 1936 (1982).

PP8.00027 Modeling the influence of interelectrode spacing in the Pulsed Discharge Nozzle , JEROME REMY, European Patent Office, NL, BART BROKS, International Marketmakers Combination, NL, WOUTER BROK, OTB engineering, NL, JOOST V.D. MULLEN, EIndhoven University of Technology, NL, ABDESSAMAD BENIDAR, LUDOVIC BIENNIER, PALMS laboratory, Universite de Rennes, F, FARID SALAMA, NASA AMES Research Center, USA — The Pulsed Discharge slit Nozzle (PDN) source was designed to produce and cool molecular ions, creating an astrophysically relevant environment in the laboratory. Using a discharge model applied to this system, a parameter study of the influence of the interelectrode distance on the plasma properties is carried out to optimize the yield of molecular ions and radicals in the PDN source. The model describes the electron density and energy, as well as the argon ion and metastable atom number density for various interelectrode distances. The results reveal that, by increasing the interelectrode distance, a positive column forms between the electrodes, thereby confirming the glow-discharge nature of the plasma. The positive column however does not contribute significantly to the formation of metastable argon atoms, and no enhanced molecular ionization is thus to be expected from an increase in said distance. The simulation results show that the PDN source might be less efficient for longer column lengths; they also provide key insight into the characteristics of interstellar species analogs in laboratory experiments.

PP8.00028 Experimental Characterization of Plasma Flow in Reconnection Scaling Experiment. , L. DORF, X. SUN, T. INTRATOR, J. HENDRYX, G. WURDEN, (LANL) — Reconnection Scaling Experiment (RSX) studies linear and non-linear evolution of up to four interacting current-carrying plasma cords with emphasis on kink instability and magnetic reconnection. During the kink instability, the presence of an axial flow gives rise to a Doppler shifted frequency and rotation of the kink, which makes studying the flow important. The axial velocity, plasma density, and electron temperature in one plasma column were measured on RSX with the miniaturized Mach and triple electrostatic probes installed on 3D positioning systems. Significant plasma flow with the velocity on the order of the ion acoustic speed was detected, with the velocity decreasing downstream. 2D profiles obtained at two axial locations were then employed to estimate the radial profile of the ion viscosity using the integral momentum balance equation. The results show that the ion momentum flux is dissipated by the ion-ion viscosity due to significant radial shear of axial velocity. Chord-integrated ion temperature measurements performed at several radial locations using Doppler broadening spectroscopy show temperature of about 1eV. Comparison of the measured viscosity with Braginskii's theoretical predictions demonstrates a good agreement, which is an important new result useful for both astrophysical jets and magnetoplasmadynamic thrusters. Supported by OFES, and DOE/LANL contract DE-AC52-06NA25396.

PP8.00029 Measuring 3D plasma flow in compact toroids, SETTHIVOINE YOU, ALEXANDER BALANDIN, YASUCHI ONO, Univ. of Tokyo — The TS-3 and TS-4 experiments at the University of Tokyo shoot two compact toroids at each other to form a single compact toroid with strong plasma flows. Up to now, conventional ion Doppler spectroscopy has been used to measure toroidal plasma flows only. The observations identified the "slingshot effect" [1], which converts magnetic energy into ion thermal and kinetic energy from the 3D contraction of reconnected magnetic field lines. The ions are however accelerated in both the toroidal and the poloidal direction. This paper presents the implementation of a novel Doppler spectroscopy diagnostic, designed to obtain the full 3D plasma fluid velocity profile by tomographic reconstruction. A simulation of the experimental setup determines the minimum number of line-of-sights (projections) and their optimum locations. The synthetic noisy measurements are then fed into the reconstruction program, which uses a spherical harmonics series expansion to obtain the solenoidal component of the velocity vector [2]. Progress towards experimental measurements will be presented. The diagnostic will help determine the ion self-helicity of a compact toroid in the context of two-fluid MHD relaxation theory [3]. [1] Y. Ono et al, Phys. Rev. Lett., 76, 18 (1996) [2] A.L. Balandin, Y. Ono, J. Comp. Phys., 202 (2005) 52-64 [3] L. Steinhauer, A. Ishida, Phys. Rev. Lett., 79, 18 (1997)

PP8.00030 Evaluation of Kinematic Viscosity of Rotating Cylindrical Plasmas Using Flow Velocity Profile Measurements[1], SHINJI YOSHIMURA, National Institute for Fusion Science, Japan, MASAYOSHI TANAKA, Kyushu Univ., Japan — Viscosity plays a crucial role in determining plasma flow structures. In torus plasmas, for example, the poloidal plasma flow driven by radial electric field produces the toroidal flow through the effect of viscosity. In a laboratory plasma, spontaneous formation of a stable vortex with a density hole around the central axis has been observed. The vorticity distribution around the central axis is well approximated by Burgers vortex in viscous fluids. The kinematic viscosity estimated from the size of the vortex is three to four orders of magnitude larger than the classical value. Although the importance of viscosity on flow structure formation is well recognized, viscosity measurements in laboratory plasmas have been seldom performed. Here we present and discuss an evaluation method of effective plasma viscosity utilizing flow velocity profile measurement. We consider the azimuthal component of ion fluid equation imposing axisymmetric condition. Then the kinematic viscosity is expressed by known quantities related to the flow profile. The result obtained by applying this method to a rotating argon plasma will be shown in the meeting.

[1]This work was partially supported by Grant-in-aid from JSPS No.19740348.

PP8.00031 Dynamics of Magnetic Flux Ropes in a Laboratory Plasma[1], ERIC LAWRENCE, WALTER GEKELMAN, UCLA — The behavior and interaction of magnetic flux ropes have long been a topic of interest to solar and space plasma physicists. (Gekelman, et al. IEEE Trans. Plasma Sci. **20**, 614. Furno, et al. Phys. Plasmas **12**, 055702.) Very few laboratory experiments have been performed as it is necessary to have a relatively collisionless plasma and currents with significant self-generated fields. Movable lanthanum hexaboride (LaB_6) cathodes have been developed to study the 3D dynamics of flux ropes in the Large Plasma Device (LaPD). Each 2.5 cm LaB_6 cathode can produce current densities of 5-20 A/cm^2 and $\Delta B/B \sim 10\%$. The background plasma ($n \sim 2 \times 10^{12}$ cm^{-3}, $d \sim 60$ cm, $L \sim 18$ m, and $\tau_{\text{rep}} = 1$ s) is produced with a DC discharge using a pulsed barium oxide-coated cathode. The two or more current channels are created by biasing the LaB_6 cathodes with respect to a grid anode at the opposite end of the chamber. They are emitted parallel to each other and the guide field. $\mathbf{J} \times \mathbf{B}$ forces cause the currents to move across the field and interact. Each cathode can be positioned freely within a transverse plane of the cylindrical LaPD. We plan to make detailed volumetric measurements of the magnetic fields and flows generated by the current channels. Diagnostics include $\dot{B}$, Langmuir, and Mach probes, and laser induced fluorescence.

[1]Research is supported by the Department of Energy (grant DE-FG02-03ER54717).

PP8.00032 Ultracold Plasma Expansion in Magnetic Field, XIANLI ZHANG, ROBERT FLETCHER, STEVEN ROLSTON, Joint Quantum Institute, Department of Physics, University of Maryland — We image the ion distribution of an ultracold neutral plasma by extracting the ions with a high voltage pulse onto a position-sensitive detector. Early in the lifetime of the plasma, the size of the image is dominated by the Coulomb explosion of the dense ion cloud. At about 20 microseconds the image size is at a minimum and then linearly increases, reflecting the true size of the plasma. The ion cloud maintains a Gaussian density profile throughout the lifetime of the plasma. By 2-D Gaussian fitting of the ion image, we obtain the transverse width, perpendicular to an applied magnetic field. The longitudinal width is obtained from the temporal width of the ion current. Without magnetic field, the plasma expansion velocity at different initial electron temperatures matches the result obtained by measuring the plasma oscillation frequency (Killian etc, PRL, 85, 2 (2000)). As we increase the magnetic field up to 70 Gauss, we find that the expansion velocity decreases, roughly scaling as B$^{-1/2}$. This field dependence is unlike expectations from ambipolar diffusion, which has a diffusion constant that scales as B^{-2}. Possible models for the expansion will be discussed.

PP8.00033 Models of low-beta plasma expansion across magnetized vacuum[1], D.V. ROSE, D.R. WELCH, T.C. GENONI, Voss Scientific, LLC — Detailed understanding of the microphysics associated with dynamic penetration of low-beta plasmas across magnetic fields has important implications for a number of applications including magnetic-fusion-energy (MFE), high-power transmission-lines, and charged-particle-beam diodes. Analytic models providing linear growth rates and characteristic wavelengths and frequencies for unstable modes at the interface between plasma and vacuum regions are presented and compared with detailed particle-in-cell simulations. The simulations treat both collisionless and collisional plasma regimes in a variety of configurations. Results of this combined theoretical analysis are compared with measurements from several experiments including magnetized electron-beam-diodes and high-power, magnetically-insulated transmission-lines. Potential applications of this modeling to MFE are discussed.

[1]Work supported by the U.S. DOE.

PP8.00034 Numerical Modeling of a Magnetic Nozzle, MIKHAIL TUSHENTSOV, BORIS BREIZMAN, ALEXEY AREFIEV, The University of Texas at Austin — We present computational study of a magnetic nozzle, which is a component of the VASIMR (Variable Specific Impulse Magnetoplasma Rocket) plasma-based propulsion system for a space vehicle. The magnetic nozzle transforms ion gyromotion into directed axial motion, adiabatically accelerating the plasma, and enabling plasma detachment from the spaceship via self-consistent magnetic field modification. VASIMR employs ion cyclotron resonance heating to deposit rf-power directly to the plasma ions created by the low energy plasma source. We have developed a numerical code to model the axisymmetric nozzle within the framework of collisionless MHD with an azimuthal ion velocity spread. The code implements a reduced model that consists of truncated steady-state equations for the velocity space moments of the ion distribution function and takes advantage of the plasma flow paraxiality. This makes it possible to study the conversion of the ion gyro-energy at the nozzle entrance into the energy of the directed flow at the exhaust. The magnetic field in the vacuum, which is not assumed to be paraxial, is calculated using a given magnetic coil configuration in the presence of plasma. From the computed steady-state flow configuration, the code evaluates magnetic nozzle efficiency, defined as the ratio of the axial momentum flux in the outgoing flow to the axial momentum flux in the incoming flow.

PP8.00035 Ambipolar acceleration of ions in a magnetic nozzle , ALEXEY AREFIEV, BORIS BREIZMAN, Institute for Fusion Studies, The University of Texas at Austin — We consider collisionless plasma flow through a nozzle that has a magnetic mirror configuration. The incoming subsonic flow of cold ions is accelerated towards the mirror by an ambipolar electric field resulting from the electron pressure. The flow velocity achieves the speed of sound in the mirror, after which the flow becomes supersonic and further accelerates downstream. For incoming Maxwellian electrons, plasma density upstream from the mirror satisfies the Boltzmann relation, with $n \propto \exp(|e|\varphi/T)$, where φ is the electrostatic potential. Downstream from the mirror, the Boltzmann relation is no longer valid as some areas of phase-space become depleted in a collisionless flow. The depletion results from the nonmonotonic nature of the effective potential $U = \mu B - |e|\varphi$ for electrons with sufficiently large magnetic moment μ. We examine how the depletion of the electron population affects the profile of the electrostatic potential, the plasma density profile, and the ensuing ion acceleration.

PP8.00036 Plume Narrowing in a Cylindrical Hall Thruster[1] , NATHANIEL FISCH, PPPL, AMNON FRUCHTMAN, Holon, YEVGENY RAITSES, PPPL, JEAN MARCEL RAX, Ecole Polytechnique — The cylindrical Hall thruster features high ionization efficiency, quiet operation, ion acceleration in a large volume-to-surface ratio channel, and performance comparable with the state-of-the-art conventional Hall thrusters [1]. The magnetic field of the cylindrical Hall thruster also differs from conventional annular Hall thrusters in that significant numbers of electrons can be trapped through magnetic-electric mirroring. Recently, by overrunning the discharge current, these thrusters also featured very significant plume narrowing, accompanied by significantly enhanced efficiencies [2]. This plume narrowing may be related in detail to the unusual magnetic configuration of the cylindrical thruster and the populations of electrons that it can support.

[1] Y. Raitses and N. J. Fisch, Parametric Investigations of Non-Conventional Hall Thruster, Physics of Plasmas 8, 2579 (2001).
[2] Y. Raitses, A. Smirnov, and N. J. Fisch, Enhanced Performance of Cylindrical Hall Thrusters, Applied Physics Letters 90, 221502 (2007).

[1]This work was supported by the AFOSR and US DOE.

PP8.00037 Z PINCHES, X PINCHES, EOS, AND HEDP —

PP8.00038 Time dependent VISAR current diagnostic for pulsed power loads[1] , KYLE PETERSON, RAYMOND LEMKE, Sandia National Labs — B-dot probes, placed in the power feed slightly upstream of the load, are the standard technique of measuring the current delivered to pulsed power loads such as Z pinches. Since current losses may still occur downstream of the probe, the measured signal may not represent the current actually delivered to the load. In this paper, a method is proposed to measure the time dependent current actually delivered to the load with potentially much higher precision than B-dot probes. In this method, the velocity induced by magnetic pressure exerted on a metallic wafer is recorded with a velocity interferometer for any reflector (VISAR) probe located after the load. Then, a parallel optimization code is used to vary the current profile in 1D simulations until the calculated velocity profile matches the experimentally measured velocity profile. Design constraints, sensitivity, and error will be discussed as well as considerations for an intense radiative environment.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

PP8.00039 Validation of an ablation model for simulating wire array z-pinches[1] , R.W. LEMKE, E.M. WAISMAN, E.P. YU, D.B. SINARS, T.A. HAILL, T.A. BRUNNER, H.L. HANSHAW, M.E. CUNEO, M.P. DESJARLAIS, T.A. MEHLHORN, Sandia National Laboratories — We have developed a 3D computational model of cylindrical wire array z-pinches. In lieu of simulating individual wires, we have incorporated a steady state model of wire ablation physics [E. P. Yu, B. V. Oliver, P. V. Sasorov et al., Phys. Plasmas 14, 022705 (2007)] into our 3D, radiation MHD code ALEGRA. We present results of a validation study using radiation pulses, currents, and density profiles from experiments with single wire arrays on the Z accelerator. By tuning the ablation rate in 2D and 3D simulations of arrays with different masses, radiation pulses are produced that are within the measurement uncertainty, which indicates how the mass ablation rate scales with wire radius. Azimuthal current paths in 3D simulations of a 60 degree periodic wedge lead to mass and current distributions that are significantly different than in 2D, and are more consistent with observations.

[1]Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US Department of Energy under Contract No. DE-ACO4-94AL85000.

PP8.00040 Two-Dimensional Radiation MHD Modeling of Gas Puff Z-Pinch Implosions[1] , J.W. THORNHILL, J.L. GIULIANI, Y.K. CHONG, J. DAVIS, A. DASGUPTA, Plasma Physics Division, Naval Research Laboratory, R.W. CLARK, K.G. WHITNEY, Berkeley Scholars, Inc., C. DEENEY, DOE/NNSA — A 2D radiation MHD model was recently developed to investigate large diameter nozzle argon Z-pinch experiments performed on the Decade Quad and Z generators.[2] This model incorporates into the Mach2 MHD code a self-consistent calculation for non-LTE kinetics and ray trace based radiation transport. Such a method is necessary in order to model opacity effects and the high temperature state of these K-shell emitting plasmas. Here, the model is used to demonstrate that increasing the spatial resolution produces significantly better agreement between calculated and experimental current profiles, implosion times, and K-shell radiative powers than attained previously. The resolution is increased by employing a moving rectilinear grid for which each radial grid line moves with the axially averaged radial Lagrangian velocity. The 2D results are processed to generate axially and temporally resolved spectra. By comparing them with experimental spectra, one can assess the capability of a 2D code to accurately model the multi-dimensional Z-pinch dynamics.

[1]Work supported by DOE/NNSA.
[2]J.W. Thornhill, et. al. Phys. of Plasmas **14**, 063301 (2007).

PP8.00041 Lumped-state CRE Modeling of the Ionization Dynamics of O- and N-like Krypton[1] , K.G. WHITNEY, Berkeley Scholars Inc., A. DASGUPTA, J.W. THORNHILL, J. DAVIS, Plasma Physics Division, Naval Research Laboratory — An often used approximation employed to simplify the problem of modeling the L- and M-shell ionization dynamics of moderate to high atomic number plasmas is to lump the states within each $n\ell$ multiplet of each ionization stage, and historically, this approximation has been applied assuming the multiplet substates are in LTE with respect to one another. In both Fe and W Z-pinch plasmas, this assumption has been shown to break down in ionization stages where the ground state has no multiplet structure [2]. In this talk, we study the subpopulation dynamics in O- and N-like ionization stages where significant amounts of population can be stored in excited states and where ground states have multiplet structure. The non-LTE behavior of the following states is calculated: the ground states, the $\Delta n = 0$, and the $2p^3 3\ell$ or $2p^2 3\ell$ excited states of O-like and N-like Kr respectively, and used to determine the impact on lumped state excitation and ionization rates and on the MHD of Z-pinch Kr implosions. In particular, the reduction of the Einstein decay rates of the $n = 3$ states as a function of ion density is calculated.

[1]Work supported in part by DoE/NNSA.
[2]K. G. Whitney, et. al., J. Phys. B, **40, 2747 (2007).**

PP8.00042 Wire Ablation Plasma Source Studies at Sandia National Laboratories[1] , M.D. JOHNSTON, K. HAHN, B.V. OLIVER, T.A. MEHLHORN, Sandia National Laboratories, D.W. DROEMER, R.L. STARBIRD, National Security Technologies, Y. MARON, E. KLODZH, E. STAMBULCHIK, Weizmann Institute of Science — Experiments are underway to investigate wire ablation plasmas as potentially tunable sources for applications such as intense electron beam transport and focusing. For these studies, one or more fine wires (100 micron diameter) are driven by a microsecond long, capacitive discharge (80kA, 100kV) to generate a plasma. High resolution visible/uv spectroscopy is used to spatially and temporally characterize the plasma throughout the pulse. Measured lineshapes and intensities are compared with time-dependent, collisional-radiative calculations to obtain plasma densities and temperatures. Changes in drive current, wire geometry, and materials are studied to determine the extent to which ablation plasma parameters can be controlled. Results are compared to MHD calculations and scaling laws for plasma mass ablation rates from wires.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

PP8.00043 Investigations of stagnated plasma conditions and opacity for K-shell x-ray sources at the Z Accelerator , C.A. COVERDALE, Sandia National Labs, C. DEENEY, NNSA-DOE HQ, J.P. APRUZESE, Naval Research Lab, B. JONES, Sandia National Labs, P.D. LEPELL, Ktech — In recent years, experiments have been performed at the Z accelerator to study K-shell x-ray sources, including Al (1.7 keV), Ar (3.1 keV), Ti (4.7 keV), SS (6.7 keV), and Cu (8.4 keV). K-shell scaling theories have shown that the temperature of the plasma necessary to produce the K-shell varies with atomic number, $T_e = 0.3*Z^{2.9}$ eV, where Z is the atomic number and T_e is the electron temperature. This suggests that for Cu, T_e must be $>$ 5 keV. In this presentation, variations observed in T_e and ion densities from the different load materials are presented. These plasma conditions are inferred from time-integrated, spatially-resolved spectra, and spatially-integrated, time-resolved spectra. Measured T_e confirm the scaling theory predictions, although in some cases the conditions are achieved only in isolated regions of the pinch. The impact of opacity on the K-shell emissions has been directly observed by comparing the line intensities from optically thin dopant materials with those of the main load constituents. Al loads show significant opacity; by contrast, Cu loads appear to be optically thin. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

PP8.00044 Quantitative investigation of mass ablation rates of wire arrays at current levels from 80kA to 1MA[1] , S. BOTT, D. HAAS, F. BEG, Department of Mechanical and Aerospace Engineering, University of California San Diego, U. UEDA, Y. ESHAQ, Physics Department, University of California San Diego, D. HAMMER, B. KUSSE, J. GREENLY, T. SHELKOVENKO, S. PIKUZ, I. BLESENER, R. MCBRIDE, J. DOUGLASS, K. BELL, P. KNAPP, Laboratory for Plasma Studies, Cornell University, J. CHITTENDEN, S. LEBEDEV, S. BLAND, G. HALL, F. SUZUKI VIDAL, A. MAROCCHINO, A. HARVEY-THOMPSON[2], Blackett Laboratory, Imperial College London — We present investigations of mass ablation rates in x-pinches and wire arrays at different current levels. Interferometry and radiography are used with x-ray framing cameras to investigate ablation from 80 kA to 1MA. The radial ablation flare structure is studied, along with the formation of precursor plasma structures. Quantitative comparisons will be made to analytical and MHD modeling.

[1]Work is supported by DOE Junior Faculty Grant DE-FG02-05ER54842, and a grant from the Center of Excellence for High Energy Density Physics, Cornell University.
[2]Work at Imperial College London is sponsored by the NNSA under DOE Cooperative Agreement DE-F03-02NA00057.

PP8.00045 Quantitative Measurements of Ablation in Wire Array Z-Pinches , A. HARVEY-THOMPSON, S.V. LEBEDEV, S.N. BLAND, J.P. CHITTENDEN, G.N. HALL, J.B.A. PALMER, F. SUZUKI-VIDAL, Imperial College London, S.C. BOTT, University of California, San Diego — The long-time scale ablation of the wires in a wire array z-pinch is crucial in determining its subsequent implosion and X-ray emission. Using a combination of interferometry and Faraday probing, we report on direct measurements of the current and mass density profiles in cylindrical, radial and inverse wire array z-pinches leading up to and during implosion. The results are compared and contracted to the rocket ablation model and to both 2 and 3-D MHD simulations. This research was sponsored by Sandia National Labs and the NNSA under DOE Cooperative Agreement DE-F03-02NA00057.

PP8.00046 Mitigation of end-effects in wire array z-pinches through hardware modification[1] , D.J. AMPLEFORD, C.A. JENNINGS, B. JONES, Sandia National Laboratories, J.P. CHITTENDEN, S.V. LEBEDEV, S.N. BLAND, S.C. BOTT, Imperial College London — Symmetry is a crucial factor for various applications of wire array z-pinches, including Inertial Confinement Fusion and K- shell x-ray source development. Previous work has shown that a non-uniformity is initiated near the cathode wire contact of a z-pinch. An imploding bubble expands axially until it stagnates prematurely on axis prior to the main x-ray pulse, leading to regions near the cathode in which no x-ray output is present at peak emission. The effects of such non-uniformities are likely to be particularly significant for the large initial load diameters used to achieve appropriate plasma conditions for K-shell emission from mid-Z elements at facilities such as Z. We discuss experiments on the Saturn accelerator which attempt to mitigate this effect by placing a step on the cathode to obstruct the propagation of the bubble towards the axis, hence preventing the non-uniformity on axis.

[1]Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's NNSA under contract DE-AC04-94AL85000.

PP8.00047 Relative Timing of Coronal Plasma Formation for Individual Wires in a Wire Array Z-Pinch , PATRICK KNAPP, D.A. CHALENSKI, J.D. DOUGLASS, J.B. GREENLY, R.D. MCBRIDE, S. PIKUZ, T. SHELKOVENKO, D.A. HAMMER, B.R. KUSSE, LPS Cornell University — We are investigating the initial stages of plasma formation around individual wires in low-wire-number wire-array z-pinches using the 1 MA COBRA pulsed power generator. The experiments are designed to examine the time-dependence of the current distribution among individual wires and pairs of wires in wire-array z-pinches using 5-10 aluminum or tungsten wires. To accomplish this we inductively isolate the wires, or pairs of wires, from each other using segmented load hardware. Each segment is able to hold one or two wires and is connected to machine ground through its own return current post. Experimental goals include determining the timing of the initiation of coronal plasma around each wire and determination of parameters that affect this timing. In addition, we will compare the early time rate of rise of the total currents from the segmented anode experiments to that from conventional arrays in order to make estimates of the temporal spread in coronal plasma formation when the anode is not segmented. *This research was supported by the Stewardship Sciences Academic Alliances program of the National Nuclear Security Administration under DOE Cooperative agreement DE-FC03-02NA00057 and by Sandia National Laboratories contract AO258.

PP8.00048 Time Evolution of the Magnetic Field Topology of Cylindrical Wire Array Z-Pinches , MATTHEW MARTIN, JOHN GREENLY, CHARLES SEYLER, Laboratory of Plasma Studies, Cornell University — We study the influence of the magnetic field topology and the global field penetration time on the ablation plasma dynamics of individual wires in wire array Z-pinches. Knowledge of the magnetic field configuration is necessary for understanding the ablation plasma acceleration process near the wires and the validity of constant ablation velocity approximation as applied to the 1 MA COBRA pulsed power generator. Three-dimensional resistive MHD simulation results suggest that a change in the global magnetic field topology is critical to initiating inward flow of the ablation plasmas. These simulation results are investigated experimentally by using B-dot probes to track the evolution of the field topology over time for small wire number cylindrical arrays on COBRA. This research was supported by the Stewardship Sciences Academic Alliances program of the National Nuclear Security Administration under DOE Cooperative agreement DE-FC03-02NA00057.

PP8.00049 Studies of the Dynamics of Ablation Stream development in Wire Arrays on COBRA[1] , JOHN GREENLY, MATTHEW MARTIN, CHARLES SEYLER, Cornell University — Wire-array simulations with the 3D GORGON code (see adjoining poster by Martin et al.) show a characteristic evolution in the development of streams of ablated material ejected from the wires toward the array axis. In simulations of aluminum arrays, the fundamental behavior occurs in two steps. The first is the development of coronal plasma that is trapped around the wire core in closed "local" magnetic flux. This coronal plasma, together with the closed flux, is then accelerated inward after a certain "dwell" time, leaving behind a radially distributed current density with entirely open "global" magnetic field lines, producing smooth, distributed acceleration of ablated plasma inward from the wire core until the onset of the final implosion. Interpretation of these dynamics in terms of simple physical modeling will be discussed, and experimental evidence of these phenomena from imaging and magnetic field diagnostics on arrays on the COBRA facility at Cornell will be presented.

[1]This research was supported by the Stewardship Sciences Academic Alliances program of the National Nuclear Security Administration under DOE Cooperative agreement DE-FC03-02NA00057.

PP8.00050 Studies of Hot Spots in Wire-Array Z-Pinches and X-Pinches[1] , KATE BELL, TATIANA SHELKOVENKO, SERGEY PIKUZ, DAVID HAMMER, JONATHAN DOUGLASS, RYAN MCBRIDE, JOHN GREENLY, Cornell University — Wire array Z-pinches and X-pinches radiate in both the soft (sub-keV) and hard (multi-keV) x-ray ranges. Hot spots are brief and intense x-ray bursts at localized small points within a Z- or X-pinch. Experiments have been carried out on the 1MA COBRA and 0.5 MA XP pulsed-power generators to investigate the temporal development, spatial structure, and x-ray emission structure of the hot spots in X-pinches and Z-pinches made from multiple fine metal wires. A Kentech x-ray streak camera and diamond photoconducting diodes (PCDs) with various filters were used to study the time evolution of the energy distribution emitted from the hot spots. Time integrated self emission pinhole images with various filters and time-gated four frame MCP images were used to study the spatial structure of hot spot x-ray emission.

[1]This research was supported by Sandia National Laboratories contract AO258, by DOE grant DE-FG03-98ER54496 and by the NNSA Stockpile Stewardship Academic Alliances program under DOE Cooperative Agreement DE-FC03-02NA00057.

PP8.00051 X-pinch Wire-number Scan at 1 MA , D.B. SINARS, M.E. CUNEO, D.F. WENGER, Sandia National Laboratories, J.D. DOUGLASS, R.D. MCBRIDE, S.A. PIKUZ, J.B. GREENLY, D. CHALENSKI, T.A. SHELKOVENKO, A. MINGALEEV, D.A. HAMMER, B.R. KUSSE, Cornell University, J.P. CHITTENDEN, Imperial College — X pinches driven by 0.2-0.4 MA produce 1 μm, 10-100 ps, $\sim$1 keV, $\sim$0.1x solid-density plasmas. We consider whether $\sim$1 μm plasmas are also produced at 1 or 6 MA, since such plasmas could have more extreme properties [e.g., Chittenden et al., Phys Rev Lett (2007)]. A 6 MA X-pinch on SATURN is massive at $\sim$100 mg/cm, requiring either large numbers of wires or a few very thick wires. To understand the issues with such an extrapolation, we studied 3 mg/cm X pinches on the 1 MA COBRA facility. Results from 2- to 64-wire W X pinches will be shown, along with results with novel configurations and large numbers of Ti, Al, and Mo wires. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the National Nuclear Security Administration (NNSA) under DE-AC04-94AL85000. This work was supported by Laboratory Directed Research and Development at Sandia, DOE Grant No. DE-FG03-98ER54496, by Sandia National Laboratories Contract No. AO258, and by the NNSA SSAA program, Cooperative Agreement No. DE-FC03-02NA00057.

PP8.00052 Quantification of axially correlated ablation in z-pinch wire arrays.[1] , JACOB ZIER, T. STRICKLER[2], M.R. GOMEZ, R. GILGENBACH, Y.Y. LAU, W.W. TANG, University of Michigan, D.A. HAMMER, B.R. KUSSE, J. GREENLY, J. DOUGLASS, R. MCBRIDE, D. CHALENSKI, K. BELL, P. KNAPP, W. SYED, Cornell University, COBRA TEAM — Wire array z-pinch experiments were performed on the 1 MA, 100 ns rise-time COBRA facility at Cornell University. Experiments utilized 7-wire-arrays, including one pair of identical 7.5 micron diameter tungsten wires and one pair with a 7.5 and a 5.0 micron wire, both spaced 240 nm apart. X-ray backlighters were used to image the wire cores. Axially correlated ablation regions between wires in the equal-diameter pair were observed. The unequal-diameter pair tested whether ablation regions in the smaller, more quickly ablated wire imprinted into the larger wire later in time. Comparisons will be presented of the fractional-lengths of correlated ablation regions for both cases.

[1]This work was supported by US DoE through Sandia National Laboratories award number 240985 to the University of Michigan and by the Stewardship Sciences Academic Alliances program of the NNSA under DoE Cooperative agreement DE-FC03-02NA00057.
[2]Now at PPPL

PP8.00053 A higher-dimensional theory of electrical contact resistance , WILKIN TANG, Y.Y. LAU, M. GOMEZ, R.M. GILGENBACH, J. ZIER, University of Michigan - Ann Arbor, M. HAWORTH, Air Force Research Lab, E. YU, M. CUNEO, T.A. MEHLHORN, Sandia National Laboratories — Electrical contact resistance is important to wire Z-pinches, high power microwave (HPM) sources, and carbon fiber field emitters, etc. It determines the amount of current delivered to the Z-pinch wire load, and good rf contacts are critical to HPM source development. The classic theory of Holm [1] assumes that the electrical contact has a finite area, but has a zero thickness in the direction of current flow from one region to the other to which electrical contact is to be made. In this paper, we use a simple geometry to calculate the resistance of an electrical contact that has a finite length in the direction of current flow. An analytic scaling law, to be developed, would then allow an assessment of the change in the contact resistance in response to an external force, whose presence would lead to a change of the contact geometry. This change may be related to the hardness of the materials. This work was supported by Sandia and AFRL.
[1] R. Holm, Electric Contacts (Springer-Verlag, 1967).

PP8.00054 Study of Wire Contact Resistance in Single and Multi-wire Z-Pinch Experiments , M.R. GOMEZ, J. ZIER, W. TANG, D.M. FRENCH, R.M. GILGENBACH, Y.Y. LAU, University of Michigan, M.E. CUNEO, M.D. JOHNSTON, M.G. MAZARAKIS, T.A. MEHLHORN, Sandia National Laboratories — Contact resistance of single and multi-wire array z-pinch has been measured for aluminum, stainless steel, and tungsten wires; diameters ranged from 7.5 to 30.5 micron. DC contact resistance in these experiments accounted for approximately 80% of load resistance, and resistance measurements varied from wire-to-wire by up to 15%. These DC measurements show that the resistance is highly dependent on both the wire material and the mass of the wire weights (0.8 g to 3.6 g). Marx pulses of 120 kV, 18 kA, 150 ns risetime were applied to the z-pinch. Wire plasma expansion velocity was measured using a streak camera, and expansion profile of the wires was determined using laser schlieren imaging. Electron temperature of individual wire plasmas is being determined by visible/UV spectra. Results will be presented of several methods being explored to reduce the contact resistance. *This work was supported by U. S. DoE through Sandia National Laboratories award number 240985 to the University of Michigan. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

PP8.00055 Designs and Plans for MAIZE: a 1 MA LTD-Driven Z-Pinch , R.M. GILGENBACH, M.R. GOMEZ, J. ZIER, W. TANG, D.M. FRENCH, B.W. HOFF, N. JORDAN, E. CRUZ, Y.Y. LAU, T. FOWLER-GUZZARDO, J. MEISEL, University of Michigan, M.G. MAZARAKIS, M.E. CUNEO, M.D. JOHNSTON, T.A. MEHLHORN, Sandia National Laboratories, A.A. KIM, V.A. SINEBRYUKHOV, Institute for High Current Electronics — We present designs and experimental plans of the first 1 MA z-pinch in the USA to be driven by a Linear Transformer Driver (LTD). The Michigan Accelerator for Inductive Z-pinch Experiments, (MAIZE), is based on the LTD developed at the Institute for High Current Electronics, utilizing 80 capacitors and 40 spark gap switches to deliver a 1 MA, 100 kV pulse with <100 ns risetime. Designs will be presented of a low-inductance MITL terminated in a wire-array z-pinch. Initial, planned experiments will evaluate the LTD driving time-changing inductance of imploding 4-16 wire-array z-pinches. Wire ablation dynamics, axial-correlations and instability development will be explored. *This work was supported by U. S. DoE through Sandia National Laboratories award number 240985 to the University of Michigan. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

PP8.00056 Measurements of plasma conditions in precursor plasmas at the 1-MA Zebra facility , N.D. OUART, University of Nevada, Reno, C.A. COVERDALE, Sandia National Laboratories, A.S. SAFRONOVA, V.L. KANTSYREV, K.M. WILLIAMSON, I. SHRESTHA, G.C. OSBORNE, University of Nevada, Reno, C. DEENEY, NNSA, DOE — Precursor plasmas, both the early time precursor flow of mass and the accumulation of this material on axis, were observed on many z-pinch experiments at various facilities, including low current (< 1MA) and high current (>15 MA, Z) facilities. The impact of these precursors on stagnated plasmas, and targets such as those used for ICF experiments, is still under evaluation. Experiments were performed at the UNR 1-MA, 100ns Zebra facility to study these precursor plasmas with Cu wire arrays. Significant precursor radiation at photon energies > 1 keV was observed on filtered PCDs. T_e and n_e of the precursor radiation were obtained from modeling of time-resolved spectroscopy of the Cu L-shell emissions for 6 wires on 12mm diameter loads. The precursor plasma temperatures are consistently >250eV. Time resolved pinhole images were also collected, which show bright spots of radiation along the axial length of the pinch. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US DOE under Contract DE-AC04-94AL85000. Work was also supported by the DOE/NNSA Coop. agr. DE-FC52-06NA27616, 06NA27588, 06NA27586, and by fellowship from the NPSC with SNL.

PP8.00057 Implosion Dynamics and X-Ray Production in Cylindrical Wire Arrays 1-16 mm in Diameter , ABDELMOULA HABOUB, VLADIMIR IVANOV, VLADIMIR SOTNIKOV, ALEXEY ASTANOVITSKIY, ALEXEY MOROZOV, SARA ALTEMARA, CHRIS THOMAS, VIDYA NALAJALA, STEVE BATIE , University of Nevada, Reno — Implosions and x-ray production in low wire number cylindrical wire arrays 1-16 mm in diameter were investigated in the 1-MA Zebra generator. Wire arrays 2-5 mm in diameter produce enhanced soft x-ray power in comparison with 12-16-mm diameter loads. Compact cylindrical arrays generate a high power x-ray pulse with a short 6-ns rising edge despite a fall of calculated kinetic energy of imploding plasma. Ablating plasma accumulates faster in volume of compact arrays and small-scale plasma turbulence could be involved to fast plasma heating. In 1-mm 8 wire cylindrical loads radiated power drops and the soft x-ray pulse has a multi-burst structure that is similar to x-ray radiation of the single wire z-pinch. Implosion dynamics and precursor formation are compared in wire arrays of different diameters. Work was supported by the DOE/NNSA under UNR grant DE-FC52-06NA27616.

PP8.00058 Effect of an axial wire on wire array z-pinch dynamics[1] , R. PRESURA, D. MARTINEZ, S. WRIGHT, C. PLECHATY, S. NEFF, L. WANEX, University of Nevada, Reno, D. AMPLEFORD, Sandia National Laboratories — Conical wire arrays have previously been studied at Imperial College mainly as a source of plasma flows similar to astrophysical jets. The central region of the array itself is well suited to studying the z-pinch stability in the presence of axial flows. Supersonic plasma streams converge on the array axis, where the energy associated with the radial momentum is thermalized and radiated, whilst the axial component is maintained. Placing a wire on axis is expected to introduce a radial profile of the axial velocity and to provide early on a current carrying path for the plasma flowing along the axis. The experiment investigated the effect of a central wire upon Al wire arrays at 1 MA. The results were compared with reference results - conical arrays without central wire and cylindrical arrays with and without central wire. The inclusion of the axial wire significantly affected the dynamics of the conical wire array implosion. Time integrated self-emission pinhole imaging shows that the axial wire allows the stagnated pinch to become significantly more uniform. The broad spectral range radiation measured with bolometers indicates that the presence of the axial wire on axis causes an enhancement in the total energy emitted.

[1]Supported by DOE/NNSA grant DE-FC52-06NA27616

PP8.00059 Investigation of particle beams in 1-MA wire array z-pinches by Faraday cups , A.A. MOROZOV, A. HABOUB, V.V. IVANOV, V.I. SOTNIKOV, R. PRESURA, A.L. ASTANOVITSKIY, T. JARRETT, V. NALAJALA, S.D. ALTEMARA, C.M. THOMAS, University of Nevada, Reno — A single Faraday cup and a linear array of cups were applied to investigate generation of particle beams in implosions of wire arrays in the 1-MA Zebra generator. The linear array includes five Faraday cups placed on the length of 16 mm and provides measurements of particle beams with spatial and temporal resolution. Cylindrical, nested and star-like arrays were investigated with focus on generation of electron beams. Experimental results are compared with different models of generation of particle beams. Work was supported by the DOE/NNSA under UNR grant DE-FC52-06NA27616.

PP8.00060 Plasma Formation from a Single Solid Conductor Carrying a Multi-Magaampere Current[1] , MILENA ANGELOVA, BRUNO BAUER, IRVIN LINDEMUTH, VOLODYMYR MAKHIN, RICHARD SIEMON, University of Nevada, Reno — A number of pulsed-power experiments in which, multi-megaampere currents melt solid conductor surfaces and turn them into hot plasmas in a matter of microseconds or less, report on the critical impact the initial plasma formation process has on the characteristics of the entire discharge. This work investigates the features of the plasma formation in a single solid conductor carrying a multi-megaampere current by means of 2-D magnetohydrodynamic simulations. The simulations employ the state-of-the-art code MHRDR, and are performed for a wide range of conductor radii. An important challenge for modeling is to predict the plasma formation threshold and, the maximum magnetic field on the conductor surface that can be obtained prior to current disruption. The results of this study can be generalized to the more complicated problem of modeling a moving liner driven by a multi-megaampere current.

[1]Work supported by DOE OFES grants DE-FG02-04ER54752 and DE-FG02-06ER54892.

PP8.00061 Radiography using a dense plasma focus device as a source of pulsed X-rays , JULIO HERRERA, FERMíN CASTILLO, ISABEL GAMBOA, JOSÉ RANGEL, Instituto de Ciencias Nucleares, UNAM — Soft and hard X-ray emissions have been studied in the FN-II, which is a small dense plasma focus machine (5 kJ), operating at the Instituto de Ciencias Nucleares, UNAM, using aluminum filtered pin-hole cameras. Their angular distribution has been measured using TLD-200 dosimeters [1]. Their temporal evolution has been observed by means of a PIN diode, and scinltillators coupled to photomultipliers outside the discharge chamber. The X rays source can be concentrated by placing a needle on the end of the electrode. X-rays crossing across a 300 micron aluminum window, through the axis of the machine, can be used to obtain high contrast radiographs, with an average dose of 0.4 mGy per shot. In contrast, the average dose with a hollow cathode is 0.2 mGy per shot. This work is partially supported by grant IN105705 de la DGAPA-UNAM.

[1] F. Castillo, J.J.E. Herrera, J. Rangel, I. Gamboa, G. Espinosa y J.I. Golzarri "Angular Distribution of fusion products and X-rays emitted by a small dense plasma focus machine" *Journal of Applied Physics* **101** 013303-1-7 (2007).

PP8.00062 Reconstruction of Neutron and Deuteron Energy Spectra in Z-pinch Experiments[1]

, KAREL REZAC, DANIEL KLIR, PAVEL KUBES, JOSEF KRAVARIK, Czech Technical University in Prague, FEE, Department of Physics, S-300 TEAM — The neutron energy spectra were reconstructed in Z-pinch experiments where deuterium atoms were present in a load. The reconstruction was based on the time-of-flight method in which time-resolved neutron detectors were placed at various distances from the neutron source. There are several theoretical approaches to the development of reconstruction algorithms (Monte Carlo, etc.). The improved Monte Carlo reconstruction technique, which simultaneously used neutron detectors placed on two opposite sites from the source, was applied to process data from experiments on the S-300 generator (Kurchatov Institute, Moscow). Since these experiments contained a small number of neutron detectors in one direction, a specific reconstruction procedure was used. From the reconstructed neutron energy spectra, also the energy distribution function of deuterons producing fusion neutrons could be calculated. The characteristics of the neutron scintillation detector and the influence of scattered neutrons were taken into account to estimate the error in the reconstruction.

[1]Work supported by MSMT No. 1P04LA235, No. 1P05ME76, No. LC528, and by GACR grant No. 20203H162.

PP8.00063 Characteristics of extreme ultraviolet radiation from laser triggered vacuum spark discharge plasma[1]

, MASATO WATANABE, NOZOMU KISHI, EIKI HOTTA, Department of Energy Sciences, Tokyo Institute of Technology — Comparative experimental studies of the vacuum spark discharge triggered by nanosecond duration laser pulses are performed under differing electrical conditions. A maximum discharge current of about 6 kA with a pulse width of 500 ns was supplied to anode-cathode gap. In our system, after laser was irradiated on electrode surface made of Sn, the main discharge will be triggered and extreme ultraviolet (EUV) radiation will occur from the generated Sn plasma between electrodes. In present study, EUV radiation emitted from laser triggered Sn discharge produced plasma was quantitatively measured using an in-band calorimeter. Both time-integrated visible image and time-resolved in-band source image measurements were also conducted using a pinhole camera system. The details of experimental results will be discussed.

[1]This work is partly supported by New Energy and Industrial Technology Development Organization (NEDO) and the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (A) and (C).

PP8.00064 Soft X-ray emission from plasma channel created by wire explosion in water

, VACLAV PRUKNER, KAREL KOLACEK, JIRI SCHMIDT, OLEKSANDR FROLOV, JAROSLAV STRAUS, Institute of Plasma Physics, v.v.i., AS CR, Za Slovankou 3, 18200 Prague, INSTITUTE OF PLASMA PHYSICS, V.V.I., AS CR, ZA SLOVANKOU 3, 18200 PRAGUE TEAM — This year it was designed and built a new apparatus SHOW-WEX (SHOck Wave – Wire Explosion), which is designed as a soft X-ray source of coherent radiation with wavelength below 20 nm. The radiation will be produced in a plasma channel created by a wire explosion in a liquid where the proximity of liquid wall stabilizes plasma channel similarly as proximity of solid wall stabilizes a Z-pinch in a capillary. Moreover, if the pressure in a liquid is increased (or locally increased by focused shock wave, which is more efficient and a higher pressure can be reached), then the plasma expansion is slowed down, the stability of plasma is enhanced, and the requirements on the driver can be softened. The first experimental data on wire explosions i.e. time dependences of charging voltage, discharge current, and soft X-ray radiation emission (measured by vacuum photo diode) are presented.

PP8.00065 Improved EOS for Describing Off-Hugoniot States in Epoxy/Foam IC Targets

, ROBERTA MULFORD, NICHOLAS LANIER, Los Alamos National Laboratory, DAMIAN SWIFT, Lawrence Livermore National Laboratory, SHANE WALTON, IAN TREGILLIS, JONATHAN WORKMAN, Los Alamos National Laboratory, PETER GRAHAM, ALASTAIR MOORE, Atomic Weapons Establishment, UK — Hydrodynamic experiments typically rely on pre-shot target characterization to predict how initial perturbations in the material interfaces will affect the late-time hydrodynamic mixing. The condition, particularly temperature, of these perturbations at the time of shock arrival dominates their eventual late-time evolution. Modeling of off-Hugoniot states in an expanding interface subjected to a shock reveals the importance of using a chemically complete description of the materials. In the experiment modeled, an epoxy/foam layered package was subjected to tin L-shell radiation, producing an expanding assembly at a well-defined temperature. The evolution of the shocked epoxy-foam interface was imaged with x-ray radiography. Modeling of the data with the hydrodynamics code RAGE required condensation of the plasma to be explicitly included. EOS were prepared that included formation of polyatomic species in the states present before shock arrival. These EOS improved fidelity of the modeling to measured details of interface behavior.

PP8.00066 Preheat Measurements for Supernova Hydrodynamics Experiments[1]

, CHRISTINE KRAULAND, CAROLYN KURANZ, PAUL DRAKE, MIKE GROSSKOPF, DUNCAN CAMPBELL, University of Michigan, TOM BOEHLY COLLABORATION — The use of multi-kilojoule, ns lasers to launch shock waves has become a standard method for initiating hydrodynamic experiments in the field of Laboratory Astrophysics. However, the intense laser ablation that creates moving plasma also leads to the production of unwanted energetic x-rays and suprathermal electrons, both of which can be sources of material preheating. In principle, this preheat can alter the conditions of the experimental setup prior to the desired experiment actually taking place. At the University of Michigan, ongoing Rayleigh-Taylor instability experiments are defined by precise initial conditions, and potential deformation due to preheat could greatly affect their accuracy. An experiment devised and executed in an attempt to assess the preheat in this specific case will be presented, along with the quantitative analysis of the data obtained.

[1]This research was sponsored by the National Nuclear Security Administration through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA00064, and other grants and contracts.

PP8.00067 Exploration of Plasma-Jet Magneto-Inertial Fusion Burn Dynamics[1]

, JOHN F. SANTARIUS, University of Wisconsin — Magneto-inertial fusion (MIF) implodes a conducting liner, compressing a magnetized plasmoid to fusion-relevant temperatures. The target's magnetic field reduces thermal conduction, and the liner's inertia provides transient plasma stability and confinement. The present work explores the burn dynamics of using plasma jets to form the MIF liner [1]. Particular attention is paid to the question of burning the thin inner layer of the liner. This exploration of MIF parameter space yields promising fast shock and long dwell time implosion modes. The investigation uses UW's 1-D Lagrangian radiation-hydrodynamics code, BUCKY, which solves single-fluid equations with ion-electron interactions, PdV work, table-lookup equations of state, fast-ion energy deposition, and pressure contributions from all species. Extensions to the code include magnetic field evolution as the plasmoid compresses plus dependence of the thermal conductivity and fusion product energy deposition on the magnetic field.

[1] Y.C. F. Thio, et al., "Magnetized Target Fusion in a Spheroidal Geometry with Standoff Drivers," in Current Trends in International Fusion Research, E. Panarella, ed. (National Research Council of Canada, Ottawa, Canada, 1999), p. 113.

[1]Research funded by DOE OFES grant DE-FG02-04ER54751.

PP8.00068 EMHD Calculations of Plasma Jet Acceleration[1] , THOMAS HUGHES, CARSTEN THOMA, Voss Scientific, JIN-SOO KIM, SERGEI GALKIN, FAR-TECH, Inc. — The acceleration of plasma jets (density $n_i \sim 10^{16} - 10^{17}$ cm^{-3}) by magnetic pressure ($B \sim 1$ Tesla) is characterized by the presence of a thin, non-equilibrium current sheath at the plasma-vacuum interface. The sheath is where the electric fields, both inductive (in the plane of the sheath) and electrostatic (normal to the sheath), that accelerate the plasma are generated. We are using a hybrid numerical model with kinetic ions and a massless electron fluid to simulate this phenomenon. A hybrid treatment is desirable because, on the one hand, it avoids the small time-steps needed by kinetic electrons, and on the other hand, the ion mean free path and ion cyclotron radius can be comparable to the sheath thickness. The latter features are important for the parameters of interest, and are outside the scope of the MHD approximation. The main numerical difficulty is in treating the motion of the thin current sheath, with its discontinuous magnetic field gradient, through the stationary mesh. In 1-D, this has been overcome by solving for the magnetic vector potential. We will present results extending the algorithm to 2- and 3-D calculations.

[1]Work Supported by DOE SBIR DE-FG02-05ER84185.

PP8.00069 Plasma jets merging simulation , S.A. GALKIN, I.N. BOGATU, J.S. KIM, Far-Tech, Inc., F.D. WITHERSPOON, M.W. PHILLIPS, HyperV Technologies Corp., T.P. HUGHES, D.R. WELCH, Voss Scientific, LLC, I. GOLOVKIN, J. MACFARLANE, Prism — The progress on numerical 3D simulations of high density high Mach number plasma jets merging is presented. The modeling was conducted with the particle-in-cell LSP code [1]. A few hypersonic plasma jets (Mach number between 5 and 50) with high density (within the range of 10^{15}-10^{17} cm^{-3}) were injected for merging in a low density low temperature neutral background gas ($\approx 10^{13}$ cm^{-3}). The dynamics of the merging was studied. Onset of a strong instability, which was observed in the modeling of two, three and five plasma merging jets [2], can essentially affect the front formation and finally can lead to a high turbulent flow. The nature of the instability is discussed. The progress on HyperV plasma accelerator experiment simulation and comparison with a recent experimental data is also reported.

[1] T. P. Hughes, S. S. Yu, and R. E. Clark, Phys. Rev. ST Accel. Beams 2, 110401, 1999.
[2] S. A. Galkin, I. N. Bogatu, J. S. Kim, to be published in PPPS/ICOP 2007 Conference Proceedings. Work is supported by the US DOE SBIR grant and by US DOE Office of Fusion Energy Sciences.

PP8.00070 Dense Hypervelocity Plasma Jets[1] , ANDREW CASE, F. DOUGLAS WITHERSPOON, SARAH MESSER, RICHARD BOMGARDNER, MICHAEL PHILLIPS, DAVID VAN DOREN, HyperV Technologies Corp., RAYMOND ELTON, ILKER UZUN-KAYMAK, University of Maryland — We are developing high velocity dense plasma jets for fusion and HEDP applications. Traditional coaxial plasma accelerators suffer from the blow-by instability which limits the mass accelerated to high velocity. In the current design blow-by is delayed by a combination of electrode shaping and use of a tailored plasma armature created by injection of a high density plasma at a few eV generated by arrays of capillary discharges or sparkgaps. Experimental data will be presented for a complete 32 injector gun system built for driving rotation in the Maryland MCX experiment, including data on penetration of the plasma jet through a magnetic field. We present spectroscopic measurements of plasma velocity, temperature, and density, as well as total momentum measured using a ballistic pendulum. Measurements are in agreement with each other and with time of flight data from photodiodes and a multichannel PMT. Plasma density is above 10^{15} cm^{-3}, velocities range up to about 100 km/s. Preliminary results from a quadrature heterodyne HeNe interferometer are consistent with these results.

[1]Work supported by the U.S. DOE Office of Fusion Energy Sciences.

PP8.00071 Probe Measurements on the HyperV Plasma Gun[1] , S.J. MESSER, F.D. WITHERSPOON, R. BOMGARDNER, A. CASE, M.W. PHILLIPS, D. VAN DOREN, HyperV Technologies Corp. — Final diagnostic measurements are underway on the HyperV plasma gun prior to installation on the Maryland Centrifugal eXperiment (MCX). These measurements will help understand penetration of the plasma jet through the MCX magnetic field. We describe both magnetic and pressure probe data. A downstream fast pressure probe confirms a steep increase in mass density coincident with the arrival of a luminous front. An array of fixed magnetic induction probes are installed in the pinch section. These are used to investigate the current and electromagnetic structures during the final phase of the plasma jet formation and acceleration. Both sets of probe data are compared to the jet's visible emissions and measurements of gun current and voltage. We also outline the design of new movable magnetic probes and access ports for optical diagnostics, to be located in the main acceleration section of the gun.

[1]Work supported by the U.S. DOE Office of Fusion Energy Sciences

PP8.00072 Laser-Driven Magnetic-Flux Compression Experiments on the OMEGA Laser , O.V. GOTCHEV, N.W. JANG, J.P. KNAUER, D.D. MEYERHOFER, R. BETTI, Laboratory for Laser Energetics, U. of Rochester — Magnetic-flux compression with lasers relies on the kinetic energy of the target shell to compress magnetic flux frozen in the highly conductive target plasma. It is expected to facilitate implosions where seed fields amplified to multimegagauss levels can reduce the thermal losses in the ICF hot spot by inhibiting the electron thermal transport out of it. This can potentially provide for implosions with higher gain (or lower ignition energy requirements) than what is possible in conventional ICF. The successful generation of very strong magnetic fields can also be used in a variety of non-fusion experiments such as laboratory astrophysics, material science, etc. The main concept and the use of a compact magnetic pulse system to seed a macroscopic magnetic field into cylindrical DD-filled targets, which are radially driven with the OMEGA laser, are described. A Helmholtz-type, single-turn coil provides the ~0.1-MG seed field. Compression of the internal magnetic flux is measured by the proton deflectrometry technique[1] optimized for this application. Results from the initial proof-of-principle experiments are discussed. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] C. K. Li *et al.*, Rev. Sci. Instrum. **77**, 10E725 (2006).

PP8.00073 Development and benchmarking of radiation transport models in LSP. , IGOR GOLOVKIN, JOSEPH MACFARLANE, PAMELA WOODRUFF, Prism Computational Sciences, PETER HAKEL, ROBERTO MANCINI, University of Nevada Reno, THOMAS HUGHES, DALE WELCH, CARSTEN THOMA, BOB CLARK, CHRIS MOSTROM, Voss Scientific, LLC, F. DOUGLAS WITHERSPOON, MIKE PHILLIPS , HyperV Technologies Corp., N.I. BOGATU, JIN-SOO KIM, SERGEI GALKIN, FAR-TECH, Inc — LSP is a hybrid particle-in-cell (PIC) code widely used to model various plasmas. We report on the recently added improvements to the modeling of radiation and atomic physics within LSP. Multi-group radiation diffusion in 2D Cartesian and cylindrical geometries has been implemented and tested. Also, the ability to utilize detailed opacity and equation-of state tables has been added. We will provide details of the implementation, as well the results of various benchmarks against analytic solutions to the radiation transport problems in multi-dimensions and against one-dimensional hydrodynamics simulations. This work is supported by the U.S. Department of Energy Office of Fusion Energy Sciences.

PP8.00074 Configuration based Collisional-Radiative Model including configuration interaction , MICHEL BUSQUET, ARTEP, Inc , contractor to NRL & LERMA-Observatoire de Paris — Atomic levels mixing through Configuration Interaction (CI) yields important effects. It transfers oscillator strengthes from allowed lines to forbidden lines, and produces strong shift and broadening of line arrays, although the total emissivity is almost insensitive to CI, being proportional to the average wave number. However for hi Z material, like Xe or Sn (potential xuv-ray source for micro-lithography), a non-LTE calculation accounting for all relevant levels wiill be untractable with billions of states. The model we constructed, CAVCRM (café-crème), is a non-LTE C.R.M. where states are configurations but it includes C.I. to give full richness of spectral quantities, using the latest version of the HULLAC-v9 suite of codes and our newly developped algorithm for large set of states with as many as 50,000 states [1].
[1] M.Klapisch et al, this conference

PP8.00075 Benchmarking algorithms for the solution of Collisional Radiative Model (CRM) equations.[1] , MARCEL KLAPISCH, ARTEP, Inc., Ellicott City, MD 21042, MICHEL BUSQUET, Observatoire de Paris, France — Elements used in ICF target designs can have many charge states in the same plasma conditions, each charge state having numerous energy levels. When LTE conditions are not met, one has to solve CRM equations for the populations of energy levels, which are necessary for opacities/emissivities, Z* etc. In case of sparse spectra, or when configuration interaction is important (open d or f shells), statistical methods[1] are insufficient. For these cases one must resort to a detailed level CRM rate generator[2]. The equations to be solved may involve tens of thousands of levels. The system is by nature ill conditioned. We show that some classical methods do not converge. Improvements of the latter will be compared with new algorithms[3] with respect to performance, robustness, and accuracy.
[1] A Bar-Shalom, J Oreg, and M Klapisch, J. Q. S. R. T.,65, 43 (2000).
[2] M Klapisch, M Busquet and A. Bar-Shalom, Proceedings of APIP'07, AIP series (to be published).
[3] M Klapisch and M Busquet, High Ener. Density Phys. 3,143 (2007)

[1]Work supported by USDOE under a contract with NRL, Laser Plasma Branch.

PP8.00076 M-shell transmission measurements of gadolinium in LTE at 30 eV , ROBERT HEETER, BRIAN WILSON, SCOTT ANDERSON, JOHN CASTOR, KEVIN FOURNIER, CARLOS IGLESIAS, STEVE MACLAREN, MARILYN SCHNEIDER, Lawrence Livermore National Laboratory — X-ray transmission opacity measurements provide a stringent test of the modeling of partly-stripped ions in high-temperature plasmas. While good agreement has been reached in studies of n=1 to n=2 (K-shell) and n=2 to n=3 (L-shell) absorption spectra, there remain significant differences between various models' predictions of the n=3 to n=4 (M-band) opacities of lanthanide elements such as gadolinium (Z=64) at temperatures in the range 25-50 eV. For example, spin-orbit splitting, orbital relaxation and configuration interaction all produce measurable signatures in the predicted M-band absorption spectra of gadolinium. Using the Omega laser facility, hohlraum experiments have been performed to study the X-ray transmission of plastic-tamped gadolinium samples in the photon energy range 1200-1400 eV at temperatures around 30 eV. The sample density and temperature were measured independently on the same laser shot. The M-band spectra of Gd are presented and compared with opacity code predictions, and some implications are discussed. This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

PP8.00077 STELLARATOR —

PP8.00078 Overview of HSX Results and Experimental Program Plan[1] , D.T. ANDERSON[2], HSX Plasma Laboratory, University of Wisconsin-Madison — HSX has recently begun operations at B=1.0 T employing fundamental ECRH at 28 GHz. T_{e0} of up to 2.5 keV and τ_E up to 5 ms have been observed with 100 kW of injected power. Significant wall conditioning has been necessary for density control under these conditions. Improvements in confinement due to quasisymmetry are observed, as at B=0.5T operation. Fundamental heating has resulted in increased plasma density (up to $<n_{el}> \sim 6 \times 10^{18}$ m^3) and a significant reduction in the non-thermal population. The MHD mode which appears driven by the precession of deeply trapped energetic electrons produced by second harmonic heating is no longer observed. The GNET and CQL3D codes are being used to understand the differences in the electron distribution functions between fundamental and 2^{nd} harmonic heating in both QHS and mirror configurations. A key element of the HSX program is investigation into the role of low effective ripple on anomalous transport. Knowledge of the radial electric field is needed to calculate the neoclassical transport. Two systems are in development to provide this data: a CHERS system based on a DNB on loan from MST, and a novel HIBP system on loan from RPI.

[1]Work supported by US DoE Grant DE-FG02-93ER54222.
[2]for the HSX Team.

PP8.00079 Transport Studies in HSX at 1 Tesla , J. LORE, D.T. ANDERSON, J.M. CANIK, K.M. LIKIN, J.N. TALMADGE, K. ZHAI, HSX Plasma Laboratory, U. of Wisconsin-Madison — To further investigate the effect of quasi-symmetry on neoclassical and anomalous transport, the HSX stellarator has recently begun regular operations at a magnetic field strength of 1 Tesla. Transport studies at 0.5 Tesla demonstrate that the electron thermal diffusivity is a factor of two smaller in the core for the Quasi-Helically Symmetric (QHS) configuration as compared to the configuration with the symmetry intentionally degraded (Mirror) due to a reduction in neoclassical transport [1]. Thermal transport analysis was complicated at 0.5 Tesla by the presence of an ECH driven suprathermal electron population, which is reduced in the higher density plasmas possible at 1 Tesla. It has also been observed that, for an identical injected power, the central temperature is double that of Mirror, with the same line averaged density in each case. A transport analysis will be presented showing the effect of higher field strength, density and injected power on electron thermal diffusivity in QHS and Mirror. This work is supported by DOE Grant DE-FG02-93ER54222.
[1] J.M. Canik et al., Phys. Rev. Letters 98, 085002 (2007)

PP8.00080 Modeling of Anomalous Transport in ECRH Plasmas at HSX , W. GUTTENFELDER, D.T. ANDERSON, J.M. CANIK, K.M. LIKIN, J. LORE, J.N. TALMADGE, HSX Plasma Laboratory, U. of Wisconsin-Madison, W. DORLAND, M. BARNES, U. of Maryland — The Weiland ITG/TEM anomalous transport model [1] is used to predict density and temperature profiles in ECRH plasmas at HSX. The local geometry approximation in [1] is replaced by the local geometry in the low-field, bad curvature region of HSX, where curvature/∇B scale lengths ($\sim$R/3) and magnetic ripple (ε_H) differ from those of a tokamak (R & ε_T, respectively). This is justified by GS2 3D [2] calculations, which demonstrate that the dominant linear instabilities (TEM) in HSX are spatially localized in this region. Growth rates from the Weiland model in this limit agree within 30% of growth rates predicted by GS2 for 3D HSX plasmas. Predicted profiles agree with a number of experimental profiles. Predicted confinement times agree within $\sim$20% of experimental confinement times. Confinement times predicted without the local geometry approximation of HSX (κ/∇B, ε_H) are 2-3$\times$ larger. This work is supported by DOE grant number DE-FG02-93ER54222. [1] H. Nordman et al., Nucl. Fusion **30**, 983 (1990) [2] E.A. Belli et al., Bull. Am. Phys. Soc. **46**, No. 8, 232 (2001)

PP8.00081 Measurement of the Pfirsh-Schlüter and Bootstrap Currents in HSX , J.C. SCHMITT, J.N. TALMADGE, D.T. ANDERSON, P.H. PROBERT, HSX Plasma Laboratory, University of Wisconsin-Madison — Pfirsch-Schlüter (PS) and bootstrap currents in the quasihelically symmetric stellarator HSX are unlike those of a conventional stellarator. The lack of toroidal curvature in HSX results in a helical PS current that rotates with toroidal angle. The PS current is smaller in size than for comparable MFEs by a factor of n-mι (=3 in HSX). The bootstrap current in HSX is opposite in direction to that in a tokamak, which reduces the rotational transform but increases the effective transform. An external Rogowski and magnetic pickup coil array measure the currents. The bootstrap current rises throughout the discharge on a 10-50 ms timescale, approaching a maximum value between 0.4-0.5 kA. The PS current rises on a 5-10 ms timescale and exhibits a dipole variation. T_e and n_e profiles are measured with a 10-chord Thomson scattering system, showing central T_e (n_e) up to 1.6 keV (5×10^{12} cm^{-3}). Varying the electron pressure profile and gradients adjusts the equilibration times and maximum values. HSX can spoil the symmetry with a set of auxiliary coils which adds a (n, m) = (4, 0) symmetry-breaking term in the |B| spectrum. This degrades the neoclassical properties of HSX and affects the resulting equilibrium currents. The measured currents will be compared to theoretical estimates. Supported by DOE grant number DE-FG02-93ER54222.

PP8.00082 ECRH at 0.5 and 1 Tesla in the Helically Symmetric Experiment[1] , KONSTANTIN LIKIN, DAVID ANDERSON, SIMON ANDERSON, CHUANBAO DENG, HUIJUAN LU, JERAHMIE RADDER, JOSEPH TALMADGE, KAN ZHAI, HSX Plasma Laboratory, University of Wisconsin - Madison — A 28 GHz gyrotron power (up to 100 kW) is used to heat HSX plasmas. The experiments are done at 0.5 T with the extraordinary wave and 1 T with the ordinary wave. The plasma stored energy, confinement time and electron temperature are studied as a function of the absorbed power and the plasma density in two magnetic configurations - quasihelical symmetric (QHS) one and second with broken symmetry. Energy confinement time is up to 5 msec in QHS configuration at the higher field. Comparisons with the international stellarator transport scaling database will be presented. In the configuration with symmetry, the central electron temperature is higher (up to 2.5 keV) than in configurations without symmetry. The electron cyclotron emission (ECE) diagnostic shows the presence of suprathermal electrons at 0.5 T. At 1 T the plasma is almost thermal. We run the CQL3D code for 0.5 and 1 T plasma parameters. ECE spectrum versus plasma density at different power level is discussed.

[1]The work is supported under DoE Grant DE-FG02-93ER54222

PP8.00083 5-D Kinetic Modeling of ECRH Plasmas in the HSX Stellarator[1] , J.W. RADDER, HSX Plasma Laboratory, University of Wisconsin-Madison, J.N. TALMADGE, K.M. LIKIN, D.T. ANDERSON, S. MURAKAMI, Department of Nuclear Engineering, Kyoto University, Kyoto, Japan, HSX PLASMA LABORATORY, UNIVERSITY OF WISCONSIN-MADISON TEAM — The global transport code GNET is used to model the evolution of the perturbed electron distribution function and radial electron transport due to electron cyclotron heating (ECRH) in the HSX stellarator. GNET solves a linearized drift kinetic equation in 5-D phase space, allowing simulation of 3-D HSX magnetic configurations. ECRH is modeled in GNET via a quasi-linear source term calculated with a separate 3-D ray tracing routine for 2nd-harmonic X-mode at 0.5 Tesla operations and 1st-harmonic O–mode at 1.0 Tesla operations. First low input power simulations ($<$ 50kW) show a slight difference between radial transport in quasihelically symmetric and mirror magnetic configurations. GNET predictions of ECRH driven flux, power deposition profiles, and implications for ECE and X-ray diagnostics will be presented.

[1]This work is supported by DOE grant number DE-FG02-93ER54222

PP8.00084 Alfvénic Modes in HSX Stellarator , C. DENG, D.L. BROWER, University of California, Los Angeles, D.A. SPONG, Oak Ridge National Laboratory, B.N. BREIZMAN, University of Texas, Austin, A.F. ALMAGRI, D.T. ANDERSON, F.S.B. ANDERSON, W. GUTTENFELDER, K. LIKIN, J. LORE, J. LU, S. OH, J.W. RADDER, J. SCHMITT, K. ZHAI, University of Wisconsin-Madison — Coherent, global fluctuations in the range of 20-120 kHz are observed for quasi-helically-symmetric, 2nd Harmonic X-mode ECRH produced plasmas in HSX (B_T=0.5T). Measurements and theory indicate that the mode with helicity m/n=1/1 is likely a global Alfvén eigenmode (GAE) driven by nonthermal electrons. Under certain conditions, a satellite mode of same helicity is observed with frequency $\sim$20 kHz higher than the primary mode. Radial structure of both the primary and satellite modes are obtained by inversion of interferometry data showing peaks at different spatial locations. Finite pressure effects, even at low plasma beta, distort the Alfven continuum and mode frequency for these low m,n modes. For HSX operation at B_T=1T with first Harmonic O-mode ECRH, the fast electron population is reduced and the mode is no longer observed. **Supported by USDOE contracts DE-FG03-01ER54615 and DE-FG02-93EE54222.*

PP8.00085 Wall Conditioning for 1T Operation in HSX[1] , A. HERR, C. CLARK, F.S.B. ANDERSON, D.T. ANDERSON, HSX Plasma Laboratory, University of Wisconsin-Madison — The Helically Symmetric Experiment (HSX) routinely runs electron cyclotron resonance heating discharges with 0.5T field on axis with stainless steel walls conditioned with helium glow discharge cleaning. When the main field is increased to 1T, impurity fueling makes density control impossible. Three techniques are explored to sustain 1T plasmas: carbonization, introduction of a limiter, and boronization. Carbonization is performed with a methane glow discharge and shows large recycling but low impurity radiation even for high injected power. A small carbon limiter is placed in the plasma to reduce wall interactions and cuts impurity influx enough to obtain stable dischages. Boronization of the HSX vacuum vessel is carried out with the solid boron precursor o-carborane. This powder is heated to form a vapor that is injected into HSX from four ovens distributed around the machine. A number of collection coupons are inserted at the vessel wall to measure film characteristics. Results are shown including Thomson scattering and spectral measurements for the three wall conditioning methods.

[1]Work supported by US DoE under grant DE-FG02-93ER54222

PP8.00086 Ion Temperature Measurements and Impurity Radiation in HSX[1] , A.R. BRIESEMEISTER, K. ZHAI, F.S.B. ANDERSON, HSX Plasma Laboratory, University of Wisconsin-Madison — Doppler broadening of impurity line radiation from HSX plasmas is measured in order to calculate the temperatures of ions in the plasma. Impurity content and temperature measurements are primarily being used at present to examine the plasma under different wall conditioning methods. When only glow discharge cleaning has been employed to condition the stainless steel first wall iron emissions are observed in 1 T operation, with a lack of density control. The correlation between edge impurity content and density control is examined for both boronized and carbonized wall conditions. Carbonized walls give good control with reduced oxygen signals and generally show lower radiated power than boronized discharges. These temperature measurements can be used as an indicator of the temperature of the primary ion species (typically hydrogen) in various magnetic configurations, and also must be known to correctly measure the plasma rotation velocity using the charge exchange recombination spectroscopy system, which is currently being implemented on HSX.

[1]Work supported by US DOE under grant DE-FG02-93ER54222

PP8.00087 Overview of Recent Results from HSX and the Planned Experimental Program[1]

, K. ZHAI, A. BRIESEMEISTER, F.S.B. ANDERSON, HSX Plasma Laboratory, University of Wisconsin-Madison — HSX has previously demonstrated that the quasihelical symmetry (QHS) does indeed improve single-particle confinement and reduce parallel viscous damping over a non-optimized 3-D configuration. New neoclassical differences have been observed under the present operating conditions including reduced thermodiffusion and electron thermal conductivity in the QHS case as compared to the mirror case. Current measurements are consistent with bootstrap calculations and show the current flows in a direction opposite to the tokamak. MHD modes have been observed tied to the presence of energetic electrons in the QHS configuration. A new ECRH transmission line now permits operation at full tube power. Our goals are to increase the density, the magnetic field and heating power to accentuate neoclassical transport relative to anomalous. A CHERS system is being implemented to infer radial electric fields for transport analysis. Preparations are near complete for going to B=1.0T for O-mode heating.

[1]Work supported by US DOE under grant DE-FG02-93ER54222.

PP8.00088 Simulation and Implementation of HIBP Electric Field Measurements for the HSX Stellarator[1]

, C. CLARK, D.T. ANDERSON, J. HILLESHEIM, HSX Plasma Lab, U. of Wisconsin-Madison, M. BINGHAM, K. CONNOR, D. DEMERS, A. DUNCKLE, P. SCHOCH, Rensselaer Polytechnic Institute — Understanding the relative roles of neoclassical and anomalous transport in advanced stellarators requires knowledge of the radial electric field. At HSX, work is under way toward measuring the radial electric field using the deflection of a beam of singly charged Cesium ions. In contrast to a typical HIBP, which measures the energy of higher charge state ions created by collisions within the plasma, this technique measures the displacement of the beam due to the plasma electric field. Recent simulations show measurable differences between ion trajectories through the HSX vacuum field and those of a typical HSX plasma with a realistic potential profile. The displacement is a path effect, but scanning the insertion angle of the beam allows the electric field in different radial locations to be diagnosed. Work to map deflected beam trajectories into radial profile scans is also under way. The ion beamline is being tested and optimized.

[1]Work supported by US Dept. of Energy grants

PP8.00089 Stability of Current-Driven Discharges in the Compact Toroidal Hybrid Experiment[1]

, S.F. KNOWLTON, G.J. HARTWELL, J.D. HANSON, J. PETERSON, J. SHIELDS, B.A. STEVENSON, Auburn University — Experiments on stability and disruption avoidance in current-driven stellarator plasmas are in progress on the Compact Toroidal Hybrid (CTH) torsatron (R = 0.75 m, a $\sim$ 0.2 m, B $\leq$ 0.7 T, $n_e \leq 10^{19}$ m^{-3}). The edge vacuum rotational transform variable in the range $0.1 < \iota/2\pi < 0.5$. Ohmic plasma currents of $I_p \leq 40$ kA are induced in target plasmas generated by 12 kW ECRH at the fundamental resonance of 18 GHz. The duration of the ohmic phase of the discharge is up to 100msec. During the plasma current rise, hesitations in the rate of current increase and associated MHD instabilities correlated with low-order rational values of the net edge rotational transform are observed. At edge rotational transform values of 1/3 or 1/2, the current usually undergoes repetitive relaxations in which the current rise is arrested, and the value of the total current drops by about 3%. Major disruptions associated with these instabilities have not yet been found to occur. Efforts to operate with an edge transform above a value of ½ with substantial plasma current are ongoing.

[1]Supported by US DOE Grant DE-FG02-00ER54610

PP8.00090 Vacuum Magnetic Field Mapping of the Compact Toroidal Hybrid (CTH)[1]

, J.T. PETERSON, J. HANSON, G.J. HARTWELL, S.F. KNOWLTON, C. MONTGOMERY, J. MUNOZ, Auburn University — Vacuum magnetic field mapping experiments are performed on the CTH torsatron with a movable electron gun and phosphor-coated screen or movable wand at two different toroidal locations. These experiments compare the experimentally measured magnetic configuration produced by the as-built coil set, to the magnetic configuration simulated with the IFT Biot-Savart code using the measured coil set parameters. Efforts to minimize differences between the experimentally measured location of the magnetic axis and its predicted value utilizing a Singular Value Decomposition (SVD) process result in small modifications of the helical coil winding law used to model the vacuum magnetic field geometry of CTH. Because these studies are performed at relatively low fields B = 0.01 - 0.05 T, a uniform ambient magnetic field is included in the minimization procedure.

[1]Supported by US DOE Grant DE-FG02-00ER54610

PP8.00091 Soft X-Ray Tomography and Temperature Measurements on the Compact Toroidal Hybrid (CTH) Experiment[1]

, G. HARTWELL, S. KNOWLTON, J. PETERSON, B.A. STEVENSON, J. HANSON, Auburn University — Soft X-Rays (SXR) arrays are used on the CTH experiment (R = 0.75 m, a $\sim$ 0.2 m, B $\leq$ 0.7 T, $n_e \leq 10^{19}$ m^{-3}, T_e(est) $\sim$ 300 eV) for tomographic reconstruction of the emissivity profile and for electron temperature measurement. The SXR tomography is done using a 60 chord system viewing the poloidal cross-section with 3 cameras each consisting of a 20-channel AXUV-20EL photo-diode array filtered with 500nm Al foil. A description of the SXR tomography cameras, the tomographic reconstruction technique and results will be given. The SXR electron temperature measurement diagnostic is a 20 chord system viewing a single toroidal cross-section. Each chord is viewed simultaneously in 2 energy bands with 2 photo-diodes. The energy bands are discriminated using filters with different thicknesses. The ratio of the 2 photo-diode signals can be used to infer the maximum electron temperature along that chord. A description of the dual-energy camera will be given as well as calculations that leading to the choice of filter material and thickness. Calibration methods will be discussed and results will be given.

[1]Supported by US DOE Grant DE-FG02-00ER54610

PP8.00092 Density Measurements of Compact Toroidal Hybrid Plasmas and Design of an Interferometer-Polarimeter Diagnostic[1]

, B.A. STEVENSON, G. HARTWELL, S. KNOWLTON, J. SHIELDS, Physics Department, Auburn University — A single-channel 4-mm heterodyne microwave interferometer (on loan from ORNL) provides line-integral density measurements of ECRH and current-driven plasmas in the CTH torsatron (R = 0.75 m, a $\sim$ 0.2 m, B $\leq$ 0.7 T, $n_e \leq 10^{19}$ m^{-3}). Densities up to the cutoff value $n_e = 0.4 \times 10^{19}$ m^{-3} are obtained in ECRH only plasmas. Higher densities are observed when ohmic heating is applied to the ECRH plasmas, however the measurement is often compromised due to refraction. The interferometer is presently set up in a double pass Mach-Zehnder configuration using a retro-reflector mounted on the inner wall of the CTH vessel. In addition, a 1mm interferometer-polarimeter system similar to 3-color FIR polarimeters [1] is currently being designed to provide electron density and current density profiles of current-driven CTH discharges in conjunction with V3FIT modeling. Details of the design will be presented. [1] J. Rommers and J. Howard, Plasma Phys. Control. Fusion 38 (1996) 1805

[1]Supported by US DOE Grant DE-FG02-00ER54610.

PP8.00093 Triple probe measurements of edge plasma parameters in the Compact Toroidal Hybrid torsatron[1] , M. CIANCIOSA, E. THOMAS, G. HARTWELL, S. KNOWLTON, Auburn University — Sheared flows arising from transverse electric fields are observed in space, laboratory and fusion plasmas. Experiments to be performed on the Compact Toroidal Hybrid (CTH) device (R = 0.75 m, a $\sim$ 0.2 m, B $\leq$ 0.7 T, $n_e \leq 10^{19}$ m^{-3}) will investigate the stability of the stellarator plasma in response to modifications of the radial electric field. In these studies, the radial electric field structure will be modified by means of a biased limiter. As a first stage of this project, measurements are needed of plasma parameters in the edge region of the CTH device. This presentation will give initial measurements of plasma parameters by means of a triple Langmuir probe. Plans for biased limiter studies on CTH will also be presented.

[1]Supported by US DOE Grants DE-FG02-00ER54476 and DE-FG02-00ER54610

PP8.00094 Calculated Refraction and Cotton-Mouton Effect for a Millimeter-wave Interferometer/Polarimeter on the Compact Toroidal Hybrid (CTH) Experiment[1] , J. SHIELDS, S. KNOWLTON, B.A. STEVENSON, J. HANSON, G. HARTWELL, Auburn University — A combined mm-wave interferometer/polarimeter based on the method of Dodel and Kunz[1] is being developed to measure the density and current profiles of current-driven discharges in the CTH torsatron (R = 0.75 m, a $\sim$ 0.2 m, B $\leq$ 0.7 T, $n_e \leq 10^{19}$ m^{-3}). Measurement of the internal magnetic field by Faraday rotation wavelengths is less costly than FIR approaches, but is more susceptible to refraction effects and the Cotton-Mouton (C-M) broadening of the polarization. Computational modeling of Faraday rotation, beam refraction, and C-M effects for wavelengths between 1.0 and 4.0 mm have been performed in 3-D geometry using plasma parameter values relevant to CTH plasmas in order to minimize the undesired refraction and C-M broadening while maintaining an adequate magnitude of Faraday rotation. Study results indicate that a 1 mm system is optimal for the CTH. 1. G. Dodel and W. Kunz, Infrared Phys. **18**, 773 (1978)

[1]Supported by US DOE Grant DE-FG02-00ER54610 and the DOE FES Fellowship Program

PP8.00095 Fast Particle Loss-Cone Measurements by the Novel Angular-Resolved Multi-Sightline Neutral Particle Analyzer (ARMS-NPA) on Large Helical Device. , EVGENY VESHCHEV, Graduate University for Advanced Studies, Hayama, Kanagawa, 240-0193, Japan, TETSUO OZAKI, PAVEL GONCHAROV, SHIGERU SUDO, National Institute for Fusion Science, Toki, Gifu 509-5292, Japan, LHD EXPERIMENTAL TEAM — The novel diagnostic of fast particles (ARMS-NPA) based on linear AXUV detector has been successfully developed and started measurements on LHD [1]. This is the first time of using AXUV detector for fast particle measurements on plasma devices. ARMS-NPA can provide time-, angular- and energy-resolved measurements of fast particles even in short-time discharges. This diagnostic can be a powerful tool in fast particle physics and confinement studies in such a complex helical plasma geometry like the one of LHD. It can become irreplaceable instrument in the checking of fast particle loss-cones existing in helical devices which were predicted by some theoretical works [2,3] and refuted by another [4]. Measurements were made in the variety of experimental conditions and compared with theoretical simulations. [1] E.A. Veshchev, T.Ozaki, *et al.*, Rev. Sci. Instrum., **77**, 10F129-1 (2006) [2] H.Sanuki, J.Todoroki and T.Kamimura. Phys. Fluids B **2** (9), 2155 (1990) [3] M. Wakatani, *Stellarator and Heliotron Devices* (Oxford University Press, Oxford, 1998) [4] T. Watanabe *et al.*, Nucl. Fusion **46**, 291 (2006).

PP8.00096 Calculation of a stable path to high beta for the LHD stellarator , BENJAMIN CARRERAS, BACV Solutions Inc., KATSUJI ICHIGUCHI, National Institute for Fusion Science — In the LHD experiments, good confinement of the plasma has been observed in a magnetic configuration with a vacuum magnetic axis located R*ax*=3.6m, where linear ideal interchange modes and Mercier modes were predicted to be unstable. In order to investigate the stabilizing mechanism of the modes, we developed a multi-scale simulation scheme [1] by utilizing the NORM code [2] and the VMEC code [3]. This scheme treats both the equilibrium change in the long time scale and the nonlinear dynamics of the instability in the short time scale simultaneously. We applied the multi-scale scheme to the low beta LHD plasma with Rax=3.6m. As beta is increased, we found a self-organization of the pressure profile. The resistive interchange modes flatten the pressure profile at the low order singular surfaces and that induces the stabilization of the Mercier modes. In this way, we find a stable path to a high beta regime.
[1] K.Ichiguchi, B.A.Carreras, J. Plasma Phys. 72(2006) 1117-1121.
[2] K.Ichiguchi et al., Nucl. Fusion 43(2003) 1101-1109.
[3] S.P. Hirshman and O. Betancourt. *J.Comp.Phys.*, **96**,99 (1991).

PP8.00097 Quasi-linear fluxes in heliotron configurations , OSAMU YAMAGISHI, MASAYUKI YOKOYAMA, HIDEO SUGAMA, National Institute for Fusion Science — Quasi-linear particle and energy fluxes by the linear gyrokinetic modes (for example, ITG modes) are investigated in heliotrons. For this purpose, the MHD magnetic configurations to model the LHD like parameters (R/a$\sim$6, L=2, M=10) are considered, which are obtained by using the VMEC. It is well known that the neoclassical ripple transport is enhanced by the helically trapped particles for low collisional regime, while its magnitude is strongly affected by the slight shift of the magnetic axis in the poloidal plane. On the other hand, in the case of quasi-linear anomalous transport, the trapped particles have tendency to make the particle fluxes negative. This tendency is strong in the heliotron configurations due to the effects of the helically trapped particles. The resulting particle pinch will be balanced with the neoclassical particle fluxes to determine the density profiles. The resulting density profiles will then affect the quasi-linear energy fluxes. By considering the different heliotron configurations with or without the neoclassical optimization, the anomalous energy transport and confinement properties will be discussed. The electromagnetic effects (for example, by KBMs), and collisional effects on the fluxes will also be shown, if possible.

PP8.00098 Shear Alfvén spectrum and mode structures for 3D configurations[1] , D.A. SPONG, Oak Ridge National Laboratory, Y. TODO, National Institute for Fusion Sciences — Energetic particle destabilized Alfvén modes are observed in a wide range of stellarator experiments. We have developed a code (AE3D) to calculate the full shear Alfvén frequency spectrum and associated mode structures for arbitrary stellarator equilibria. This is based on a Galerkin approach using a combined Fourier mode (poloidal/toroidal angle) finite element (radial) representation. It has been applied to an LHD case where Alfvén activity and enhanced ion losses were seen. Applications also are underway to other experiments, such as HSX, where ECH-driven Alfvén modes were observed. This model can form the basis for stellarator optimization targets, synthetic diagnostics, and reduced linear/nonlinear stability models. It is also applicable to tokamaks with symmetry-breaking effects. By matching observed frequencies with calculated mode structures, improved understanding of the physics mechanisms of AE modes, such as sideband coupling, damping, and enhanced fast particle losses can be developed.

[1]Acknowledgements – Research sponsored by the U.S. Department of Energy under Contract DE-AC05-00OR22725 with UT-Battelle, LLC.

PP8.00099 Magnetic islands and confinement in the H-1NF heliac[1] , SANTHOSH T. A. KUMAR, BOYD D. BLACKWELL, MICHAEL G. SHATS, JOHN HOWARD, The Australian National University, JEFFREY H. HARRIS, Oak Ridge National Laboratory — Magnetic islands in fusion devices have serious impacts on the confinement properties, including enhancement of radial transport and deterioration of plasma confinement. However, there is experimental evidence that under certain conditions, islands can induce transport barriers and thus improve confinement. Present understanding of the conditions for either deterioration or improvement in plasma confinement due to magnetic islands is far from complete. The H-1NF heliac in the Plasma Research Laboratory, ANU, provides an excellent opportunity to conduct controlled experiments on magnetic islands. The flexible coil system of H-1NF allows the magnetic configurations to vary over a wide range to accommodate or avoid major rational surfaces and islands. Our recent experiments in a low temperature RF-produced Argon plasma indicate that, under our experimental conditions, magnetic islands near the core may serve as pockets of improved plasma confinement regions. In the presence of these islands, the radial electric field near the core jumps to a large positive value, reversing its direction within the island, producing a strong electric field shear layer.

[1]This work is supported by the ARC Grant DP0344361.

PP8.00100 A Preconditioned Newton-Krylov Code for Calculating 3D MHD Equilibria with Magnetic Islands[1] , DANIEL RABURN, ALLAN REIMAN, DONALD MONTICELLO, RAVI SAMTANEY, Princeton Plasma Physics Laboratory — We have implemented a Jacobian-free Newton-Krylov method with a Levenberg-Marquardt line-search in the PIES code, which solves for 3D MHD equilibria. The algorithm has performed well in tests on helical equilibria with islands. We are investigating further techniques, such as using an adaptive preconditioner, where the limited subspace information from each linear solve is used to construct a preconditioner for future linear solves.

[1]This work was supported by DOE contract number DE-AC02-76-CHO3073.

PP8.00101 V3FIT: Three-Dimensional MHD Equilibrium Reconstruction , JAMES D. HANSON, JOHN SHIELDS, Auburn University, S.P. HIRSHMAN, E.A. LAZARUS, Oak Ridge National Laboratory, L. LAO, General Atomics, S.F. KNOWLTON, Auburn University — V3FIT is a three-dimensional MHD equilibrium reconstruction code, based on the VMEC equilibrium code. V3FIT is a general and easily extensible reconstruction code, designed so that information from many types of diagnostics can be used to determine the equilibrium. The first diagnostics included in V3FIT were magnetic diagnostics. We will present results on reconstruction using microwave interferometers and polarimeters as diagnostics. We will also show comparisons between V3FIT and EFIT reconstructions using experimental data from the DIII-D tokamak. This work is supported in part by US DOE Grant DE-FG02-03ER54692B and a US DOE Postdoctoral Research Fellowship.

PP8.00102 Studies of the neoclassical transport for CNT , BERNHARD SEIWALD, ITPCP, Graz University of Technology, VIKTOR V. NEMOV, Institute of Plasma Physics, Kharkov Institute of Physics and Technology, THOMAS SUNN PEDERSEN, Columbia University, Department of Applied Physics and Applied Mathematics, WINFRIED KERNBICHLER, ITPCP, Graz University of Technology — The Columbia Nonneutral Torus (CNT) was not optimized with respect to $1/\nu$ neoclassical transport, therefore, such studies are of interest and desirable. For such a task the code SORSSA was adapted to CNT. SORSSA computes a normalized stored energy based on a simple transport model depending on the neoclassical effective ripple $\epsilon_{\rm eff}$. For this purpose $\epsilon_{\rm eff}$ is calculated by following the magnetic field line. Because the magnetic field is computed in real space coordinates directly from coil parameters there is no restriction to the complexity of the magnetic field. First results of computations of the total stored energy are presented.
*This work, supported by the European Communities under the contract of Association between EURATOM and the Austrian Academy of Sciences, was carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission. Additional funding is provided by the Austrian Science Foundation, FWF, under contract number P16797-N08.

PP8.00103 Progress in NCSX Construction[1] , G.H. NEILSON, J.H. CHRZANOWSKI, P.J. HEITZENROEDER, M. KALISH, PPPL, J.F. LYON, B.E. NELSON, ORNL, M.E. VIOLA, M.C. ZARNSTORFF, PPPL — The National Compact Stellarator Experiment (NCSX) is being constructed at the Princeton Plasma Physics Laboratory (PPPL) in partnership with the Oak Ridge National Laboratory (ORNL). The NCSX has major radius 1.4 m, aspect ratio 4.4, 3 field periods, and a quasi-axisymmetric magnetic field. The device will provide the 3D plasma configuration flexibility and the heating and diagnostic access needed to study compact stellarator physics. The components have complex geometries and tight tolerances, but the most challenging ones are nearing completion. The vacuum vessel was completed in 2006. Delivery of the 18 modular coil winding forms was completed in 2007 and at least twelve modular coils have been fabricated, satisfying the ± 0.5 mm tolerance requirement on the current center position. The toroidal field coils are in production. Installation of tubing and diagnostic loops on the vessel is nearly complete. Preparations for assembly of modular coil subassemblies began in 2007. Plans for completing NCSX construction, including an updated schedule, will be presented.

[1]Research supported by U.S. DOE under Contracts No. DE-AC02-76CH03073 with Princeton University and No. DE-AC05-00OR22725 with UT-Batelle, LLC

PP8.00104 Magnetic Flexibility of NCSX.[1] , M.C. ZARNSTORFF, S. HUDSON, L. MAINGI, D. MIKKELSEN, N. POMPHREY, PPPL, NCSX TEAM — The National Compact Stellarator Experiment (NCSX), currently under construction, is a modular quasi-axisymmetric stellarator designed to study confinement and stability of high-beta plasmas. It has 18 modular coils, 18 planar weak toroidal field coils, and 6 pairs of poloidal field coils. Each type of coil is powered separately, providing a wide range of 3D shape flexibility. This equilibrium flexibility space has been explored to determine the range available, to identify candidate equilibria for early experiments, and to analyze the expected plasma characteristics. Vacuum equilibria, with well formed flux surfaces are found for iota (magnetic rotational transform) ranging from 0.19 to 0.9 and low effective helical ripple $< 1\%$. The effective ripple can be varied by more than a factor of 10, at fixed rotational transform. At low effective ripple, the ripple generated neoclassical transport is predicted to be negligible. At the maximum ripple, the ripple generated transport reduces the predicted plasma temperature, and this change is large enough to be measurable. The change in transform from the center to the edge can be varied from -0.1 to $+0.25$. Similar variations have been calculated for finite beta equilibria. Calculations of flux-surface quality and the effect on transport and stability will be discussed.

[1]Supported by U.S. DoE Contract DE-AC02-76-CHO-3073.

PP8.00105 Status of the QPS Project[1] , J.H. HARRIS, J.F. LYON, Oak Ridge National Laboratory, QPS TEAM — The Quasi-Poloidal Stellarator (QPS) is designed to test key physics issues at plasma aspect ratios 1/2-1/4 of other stellarators. QPS has a quasi-poloidal (linked-mirror-like) rather than quasi-toroidal (tokamak-like) magnetic configuration, which allows poloidal flows and flow shear a factor of $\sim$10 larger than in other toroidal confinement systems, and very low effective ripple to reduce neoclassical transport. It is the only toroidal device stable to drift wave turbulence over a range of temperature and density gradients and has a large fraction of trapped particles in regions of low/favorable field line curvature, which strongly reduces the drive for some trapped-particle instabilities. QPS has highly accurate coil winding forms that are cast and machined, conductor wound directly onto the winding forms, a vacuum-tight cover welded over each coil pack, coils vacuum pressure impregnated, and the winding forms bolted together to form a structural shell inside the vacuum vessel. Nine independent controls on the coil currents permit varying key physics features by a factor 10–30: the degree of quasi-poloidal symmetry, poloidal flow damping, neoclassical transport, stellarator/tokamak shear and trapped particle fraction. The current status of the project will be presented.

[1]Work supported by U.S. Dept. of Energy under Contract DE-AC05-00OR22725 with UT-Battelle LLC.

PP8.00106 FRC'S, FLOW PINCH, HBT-EP, HELIMAK, AND LDX —

PP8.00107 Summary of the Magnetized Target Fusion physics demonstration[1] , T.P. INTRATOR, G.A. WURDEN, P.E. SIECK, R.M. RENNEKE, W.W. WAGANAAR, L.A. DORF, S.C. HSU, M. KOSTORA, Los Alamos National Laboratory, R.E. SIEMON, T. AWE, Univ. Nevada - Reno, A.G. LYNN, M. GILMORE, Univ. New Mexico, J. DEGNAN, C. GRABOWSKI, E.L. RUDEN, Air Force Research Laboratory - Kirtland — We summarize a Magnetized Target Fusion (MTF) effort, whose primary goal is the first integrated liner-on-plasma physics demonstration at Air Force Research Laboratory (AFRL) in 2008. LANL physics, engineering, diagnostic coordination, and hardware at AFRL brings the Field Reversed configuration (FRC) to the liner. To minimize the technical risk, physics questions must be resolved. These require detailed instrumentation not compatible with the AFRL liner on plasma realization of this experiment. The LANL FRXL experiment is thus a separate physics oriented front end with slotted liner, radial access for probes, optical diagnostics, and magnetics. We will measure the trapped flux, plasma entry to the liner region mirror, how well the mirror trapping works, how well the FRC bounces at the end mirror, effects on the FRC lifetime, trade off of translation speed against FRC lifetime, and helicity created with conical theta coils.

[1]supported by contract DE-AC52-06NA25396.

PP8.00108 Toroidal Field and Magnetic Helicity in a Translating, High-Density Field Reversed Configuration[1] , P.E. SIECK, T.P. INTRATOR, G.A. WURDEN, Los Alamos National Laboratory — The ideal Field-Reversed Configuration (FRC) has zero toroidal field, but finite toroidal field and magnetic helicity have been observed in many translating FRCs, especially those formed via conical theta pinch. The appearance of helicity is believed to depend upon the Hall Effect. Other experiments have also observed a reduction of the toroidal field when a translating FRC is arrested in a magnetic mirror, with a corresponding increase in poloidal flux. This suggests a relaxation process that increases beta. We discuss plans to produce FRCs with varying amounts of helicity on the Field Reversed eXperiment-Liner (FRX-L) by using theta coils with a wide range of cone angles. The FRX-L program emphasizes high-density FRCs for use in Magnetized Target Fusion (MTF). Observations of helicity at higher density will improve knowledge of the role of the Hall parameter. Additional helicity may increase the stability of the translating FRC. Helicity content can thus be used to balance plasma beta against stable lifetime to provide an optimum MTF target.

[1]Supported by OFES and the DOE, LANS Contract No. DE-AC52-06NA25396.

PP8.00109 Guide and Mirror Magnetic Field Diffusion Calculations for the FRC Compression Heating Experiment (FRCHX) at AFRL , MATTHEW DOMONKOS, Air Force Research Laboratory, DAVID AMDAHL, Numerex, JAMES DEGNAN, Air Force Research Laboratory, MICHAEL FRESE, Numerex, DONALD GALE, CHRIS GRABOWSKI, SAIC, ROBIN GRIBBLE, THOMAS INTRATOR, Los Alamos National Laboratory, GERALD KIUTTU, Varitech — Calculations of the guide and mirror applied magnetic field diffusion were conducted using a commercially available generalized finite element solver. As part of the integrated FRC compression heating experiment (FRCHX), an applied magnetic field captures the translating FRC in the liner region long enough to enable compression. Solenoidal coils inject the necessary magnetic field prior to liner implosion. Since the liner implosion is underway before the FRC is injected, the magnetic flux that diffuses into the liner is compressed, and the calculations must account for the liner motion. A generalized finite element code, using appropriate simplifying assumptions, aided the design of the guide and mirror coils for the FRCHX. The code was used to determine that the Shiva Star return conductor needs to be slotted to permit magnetic field diffusion. In addition the liner motion was approximated to evaluate the field within the liner during implosion. This work is funded by the U.S. Department of Energy Office of Fusion Energy Sciences.

PP8.00110 FRC Adiabatic Compression Heating Experiments , J.H. DEGNAN, M.H. FRESE, D.J. AMDAHL, M. BABINEAU, J.F. CAMACHO, S.K. COFFEY, M. DOMONKOS, S.D. FRESE, D. GALE, C. GRABOWSKI, J.V. PARKER, D. RALPH, E.L. RUDEN, W. SOMMARS, Air Force Research Laboratory, Directed Energy Directorate, T.P. INTRATOR, G.A. WURDEN, P. SIECK, P.J. TURCHI, W.J. WAGANAAR, Los Alamos National Laboratory, R.E. SIEMON, T.J. AWE, B.S. BAUER, A. OXNER, University of Nevada Reno, A.G. LYNN, N.F. RODERICK, University of New Mexico — AFRL and LANL are developing Magnetized Target Fusion (MTF). This will use the Shiva Star capacitor bank at AFRL to implode an Al solid liner containing the target plasma to raise density and temperature. The Field Reversed Configuration (FRC) has been chosen for the target because of its stability, translatability, and divertor-like field configuration. The FRX-L experiments at LANL explore FRC formation and translation into the liner. 2D-MHD calculations with MACH2 look at translation, capturing and compressing the FRC. Extended MHD examines FRC rotation. The aforementioned guide the design of the experiment at AFRL, which called FRCHX. Formation and translation tests at AFRL are underway before the first compression heating experiment. Supported by DOE-OFES.

PP8.00111 FRC Rotation in Extended MHD Modeling[1] , MICHAEL H. FRESE, SHERRY D. FRESE, NumerEx, EDWARD L. RUDEN, JAMES H. DEGNAN, NORMAN F. RODERICK, U.S. Air Force Research Laboratory — Field reversed configurations (FRCs) are observed to develop bulk rotation. The explanation for this behavior from a particle point of view is the preferential diffusion of one sense of angular momentum through the separatrix. We demonstrate that bulk angular momentum is developed in computational simulation of FRCs with extended MHD using the Generalized Ohm's Law and without finite Larmor radius effects and explain how. We analyze the relationship of the fluid model to the hybrid particle model. These simulations are performed in geometries and with fields driven by self-consistent circuits that reflect experiments performed as part of the DoE OFES Magneto-Inertial Fusion program. The fluid point of view clarifies the cause of the rotation and allows development of applied fields to counteract the rotation.

[1]Work Supported by U.S. Department of Energy Office of Fusion Energy Science

PP8.00112 Power Balance on a High-Density Field Reversed Configuration , RICHARD RENNEKE, LANL/Purdue, TOM INTRATOR, LANL, CHAN CHOI, Purdue, GLEN WURDEN, SCOTT HSU, LANL, THEODORE GRABOWSKI, ED RUDEN, AFRL/Kirtland, WILLIAM WAGANAAR, LANL, FRX-L TEAM — An analysis of global power balance has been performed recently on the Field Reversed Experiment with Liner (FRX-L) for a high density ($> 5\times 10^{22}\ \mathrm{m}^{-3}$) Field Reversed Configuration (FRC) for the first time. Total radiated power was compared to the total power losses estimated from the power balance zero-dimensional model proposed by Rej and Tuszewski (Phys. Fluids **27**, p. 1514, 1984). The percentage of radiative losses versus total loss is an order of magnitude lower than previous lower density FRC experiments. An explanation for the beneficial effect of density is provided by an empirical scaling drawn from the tokamak database. This scaling shows that Z_{eff} has an inverse- squared dependence on density. Assuming that radiated power is due primarily to impurities in the edge plasma, this explanation is sufficient.

PP8.00113 Progress on the Colorado FRC Experiment[1] , A.D. LIGHT, C.L. ELLISON, T. MUNSAT, J.M. NUGER, W. WILLCOCKSON, S.E. WURZEL, Center for Integrated Plasma Studies, University of Colorado — Experiments have begun on a new machine for the study of turbulence, flow, stability, and cross-field transport in a field-reversed configuration (FRC). The Colorado FRC Experiment is a high-β, merged-spheromak device driven by magnetized coaxial plasma guns. A two-point biasing probe will be used to drive $E \times B$ flows. Current efforts are focused on characterizing various components and exploring the operating parameters of the device, as well as developing a diagnostic set for initial fluctuation and flow experiments. Early results and progress toward completion of the machine are presented.

[1]Supported by U.S. DOE contract DE-FG02-05ER54841

PP8.00114 Diagnostics for the Colorado FRC Experiment[1] , T. MUNSAT, C.L. ELLISON, A.D. LIGHT, J.M. NUGER, W. WILLCOCKSON, S.E. WURZEL, Center for Integrated Plasma Studies, University of Colorado — A collection of fast diagnostics is under development for studies on the Colorado FRC Experiment. Current and planned instruments emphasize high spatial and time resolution for detailed measurements of fluctuations and bulk flows. All systems are frequency-limited only by the data acquisition rate ($\geq$ 10 MHz). Diagnostics under development include a compact, 16-position, three-axis magnetic probe, a localized ion-Doppler spectroscopy instrument, a fast ion gauge for measuring transient gas pressure, a seven-channel CO_2 quadrature interferometer, a multi-channel Mach probe array, and a multi-frequency reflectometry system. Details of the instruments and preliminary measurements are presented.

[1]Supported by U.S. DOE contract DE-FG02-05ER54841

PP8.00115 Compression of compact tori by use of efficient drivers[1] , SIMON WOODRUFF, ANGUS MACNAB, Woodruff Scientific, LLC — The adiabatic compression of magnetized plasmas has come to the fore in recent times as an interesting hybrid of both inertial and magnetic fusion energy schemes, possibly allowing a means to reach fusion conditions in a compact pulsed system. Here we consider the compression both of the FRC and Spheromak, both with a coil compression [1] and with an imploding liquid liner [2]. Of critical importance in choice of target for compression is the scaling of the confinement with convergence, time-scale for compression and obtainable beta. We present analytic scaling relations for the compression schemes, and MHD simulations of the target plasmas in preparation for the design of a new experiment.

[1] P. M. Bellan Scalings for a Travelling Mirror Adiabatic Magnetic Compressor Rev. Sci. Instrum. 53(8) 1214 (1982)
[2] P. Turchi, D. J. Book, R. L. Burton, A. I. Cooper Stabilized Imploding Liner Research for High Magnetic Field Plasma Compression J. Magnetisim and Magnetic Materials 11 p373-375 (1979)

[1]Work supported by DOE under subcontract DE-FG02-07ER84924.

PP8.00116 Spectroscopic Diagnostics of the Irvine FRC , J.M. LITTLE, E.P. GARATE, W.S. HARRIS, W.W. HEIDBRINK, R. MCWILLIAMS, T. ROCHE, E. TRASK, University of California, Irvine — A spectroscopic system is developed to resolve the Hydrogen-alpha spectral line of the Balmer series in order to estimate neutral hydrogen temperatures and rotational velocities in the Irvine Field Reversed Configuration (IFRC). Light from the chamber is collected with a system of lenses and relayed via 1mm diameter fiber optic cable to a one-meter Jarrell Ash Czerny-Turner monochromator. An image intensifier is placed in series with a CCD camera at the exit slit of the monochomator to capture the image of the spectral line. The image is focused on the CCD camera with approximately 150 pixels per nanometer of wavelength, which allows a wavelength range of around 4 nm per image. The estimated resolution of the system is presently on the order of 5Å FWHM. The spectral line profile is obtained by deconvolving the measured profile with the instrument profile in IDL.

PP8.00117 Triple Probe Array on Irvine FRC , E. TRASK, E.P. GARATE, W.S. HARRIS, W.W. HEIDBRINK, R. MCWILLIAMS, T. ROCHE, UC Irvinve — A new triple probe implementation has been designed and tested on the Irvine Field Reversed Configuration (IFRC). Difficulties occur in normal triple probe measurements on IFRC due to two main reasons: short plasma lifetime and a nonconductive vacuum vessel. The new design addresses these issues by allowing pairs of probe tips to float with the plasma. The signal pairs are coupled across a wide bandwidth isolation transformer. Key features include measurement of the floating potential by capacitive coupling between the primary and secondary of the transformer, and the use of only two probe tips to extract the information necessary to solve for the electron temperature and density. The temperature is measured by differential amplification of the floating potential and capacitively-coupled high side of the double probe pair. The ion saturation current is measured by amplifying the transformer differential voltage. The electronics bandwidth is approximately 0.5 kHz to 2 MHz as tested on the bench. Initial results on IFRC indicate densities of mid 10^{12}/cc and electron temperatures of 3 to 5 eV.

PP8.00118 Ion Energy Distribution Function Measurements in the Irvine FRC , W.S. HARRIS, E.P. GARATE, W.W. HEIDBRINK, R. MCWILLIAMS, T. ROCHE, E. TRASK, Y. ZHANG, University of California, Irvine — A time-of-flight diagnostic has been implemented on the Irvine Field Reversed Configuration (IFRC) to obtain an energy distribution function from charge-exchanged neutral hydrogen. The diagnostic includes a 13cm radius slotted disk rotating at 165Hz in vacuum which chops the emitted neutrals at a rate of 27kHz. In-situ timing verification was performed with a DC xenon discharge lamp with an uncertainty less than 100ns for a 38μs chopping period. Energy calibration was accomplished with a lithium ion source in the range of 300-1500eV, presently achieving an average energy uncertainty, $\Delta E/E$, of 0.23 prior to further analysis. The diagnostic has measured neutrals in the range of 20-80eV from the Irvine FRC and the corresponding energy distribution function has been obtained.

PP8.00119 Irvine FRC Magnetic Field Structure , T. ROCHE, E.P. GARATE, W. HARRIS, W. HEIDBRINK, R. MCWILLIAMS, E. TRASK, UC Irvine — Magnetic probe arrays have been used to construct time-evolving images of the magnetic field structure in the Irvine Field Reversed Configuration (IFRC). Two radial arrays, consisting of ten probes each, measure the field in all three directions within the interior of the plasma. Axial field arrays measure field strengths adjacent to inner and outer coils. Magnetic field maps are made by moving the radial probes to different axial and azimuthal positions over a series of shots. The map covers a grid of 30 cm x 50 cm in the r-z plane with grid spacing 2.5 cm x 5 cm. Shot-to-shot variation is small enough (<10%) to use data from successive shots to interpolate magnetic field lines as they evolve in time. Reversed fields of $\sim$ 200 gauss have been measured with lifetimes of $\sim$ 40 μs. These data have been used to estimate essential IFRC equilibrium qualities/quantities such as mid-plane separatrix radii, major radius of the compact toroid, field-null location and azimuthal symmetry. During this process the background fields for shots without plasma also were measured. It has been found that some anisotropy in the background may have been the cause of undesired translational motion of the IFRC. Improvement of the background field symmetry may lead to longer lived equilibria in the desired location.

PP8.00120 Rotating Magnetic Field sustainment of hot FRCs at high zeta , ALAN HOFFMAN, HOUYANG GUO, RICHARD MILROY, University of Washington — Ultra high vacuum modifications to the TCS device have allowed FRCs to be formed and sustained by Rotating Magnetic Fields (RMF) at temperatures well over 100 eV, without increasing the RMF magnitude, B_ω. The higher temperatures result in much higher magnetic fields, B_e, and significantly higher ratios of B_e/B_ω. The ratio of average electron rotational speed to RMF frequency, called zeta, approaches unity, resulting in a maximum possible applied RMF torque on the electrons. Power is absorbed by the plasma due to oscillating axial currents (which create the azimuthal torque), proportional to B_ω^2, and due to the azimuthal FRC currents, proportional to B_e^2. Comparison of torques and powers at high and low zeta conditions shows that at low values of B_e/B_ω, most of the power absorption is due to the axial currents (proportional to B_ω^2), but at values of B_e/B_ω exceeding 10, this component becomes insignificant. Under such conditions, the cross-field plasma resistivities are only about one order of magnitude higher ($\sim$20 $\mu\Omega$-m) than necessary for modest sized reactor efficiencies.

PP8.00121 Use of a Magnetized Cascade Arc Source in TCSU to Enable RMF Formation of High Temperature FRCs , PAUL MELNIK, HOUYANG GUO, ROBERT BROOKS, ALAN HOFFMAN, KENNETH MILLER, RPPL, University of Washington — TCSU can produce 200 eV FRC plasmas out of a weakly ionized gas by means of an azimuthally rotating magnetic field (RMF) and a steady axial bias field. The seed plasma for the RMF driven FRCs is produced by an ultra-high vacuum compatible, magnetized cascade arc source. The arc source has been constructed to translate into the TCSU end section where it is fired in the presence of $\sim$ 150 mT axial magnetic field. This allows the n_e=3.3x10^{19} m^{-3}, T_e=10 eV gun plasma to stream along the axial field to the confinement section where, along with a necessary mid-plane puff of neutral deuterium, it can be used to form and sustain the FRC. Final FRC parameters depend on the condition of the gun plasma and deuterium puff parameters, as well as the degree of deuterium recycling from the wall. A fast ion gauge is used to measure the neutral pressure in the confinement section at the moment of FRC formation. The effect of varying plasma gun conditions and neutral puff parameters on FRC performance is currently being studied and results will be shown.

PP8.00122 Density and Impurity Measurements on the TCSU Experiment , CHRIS DEARDS, GEORGE VLASES, RPPL, University of Washington — TCS-U will have numerous diagnostics for density measurements including Thomson Scattering, Langmuir Probes, and a two-color interferometer. Presently only the two-color interferometer is available. Since temperature is inferred from the magnetic field and interferometer-measured density, the density measurement must be accurate and repeatable. The interferometer system on TCS-U is a two color Mach-Zehnder interferometer with an acoustic modulator to shift the reference beams by 40 MHz. The interferometer setup on TCS-U, as well as data supporting its accuracy and repeatability over a number of shots, will be discussed. Impurity measurements made using the spectrometer system, which includes three monochromators and an intensified CCD camera spectrometer, will also be discussed.

PP8.00123 Two-fluid flowing equilibria of spherical torus sustained by coaxial helicity injection , TAKASHI KANKI, Japan Coast Guard Academy, LOREN STEINHAUER, University of Washington, MASAYOSHI NAGATA, University of Hyogo — Two-dimensional equilibria in helicity-driven systems using two-fluid model were previously computed, showing the existence of an ultra-low-q spherical torus (ST) configuration with diamagnetism and higher beta. However, this computation assumed purely toroidal ion flow and uniform density. The purpose of the present study is to apply the two-fluid model to the two-dimensional equilibria of helicity-driven ST with non-uniform density and both toroidal and poloidal flows for each species by means of the nearby-fluids procedure, and to explore their properties. We focus our attention on the equilibria relevant to the HIST device, which are characterized by either driven or decaying λ profiles. The equilibrium for the driven λ profile has a diamagnetic toroidal field, high-β (β_t= 32%), and centrally broad density. By contrast, the decaying equilibrium has a paramagnetic toroidal field, low-β (β_t= 10%), and centrally peaked density with a steep gradient in the outer edge region. In the driven case, the toroidal ion and electron flows are in the same direction, and two-fluid effects are less important since the $E \times B$ drift is dominant. In the decaying case, the toroidal ion and electron flows are opposite in the outer edge region, and two-fluid effects are significant locally in the edge due to the ion diamagnetic drift.

PP8.00124 Comparison of Rotamak Plasma Discharges in Cylindrical and Spherical Devices , XIAOKANG YANG, YURI PETROV, TIAN-SEN HUANG, Prairie View A&M University — A new cylindrical chamber rotamak device with one additional magnetic coil added in the middle plane has been built and operated at Prairie View Plasma Physics Lab. A series of experiments in the cases with and without a toroidal field have been performed. The measured plasma current, density and electron temperature are roughly same as those measured in our spherical chamber device operated under the same RF generator power (200 KW / 0.5 MHz) and gas filling pressure (1.3 mTorr). In the case without a toroidal field, the typical plasma parameter for cylindrical device is I_p = 2.1 kA, T_e = 15 eV, and n_e = 1.2 $\times$ 10^{12} cm^{-3}; in the case with a toroidal field , I_p = 2.7 kA, T_e = 25 eV, and n_e = 1.4 $\times$ 10^{12} cm^{-3}. The results from both devices confirm that configuration with toroidal field is more stable and allows to achieve higher Ip with proper choice of toroidal field. Results from cylindrical chamber device show that total plasma current can be increased from 2.2 KA to 3 KA when 400A current is applied to the midplane coil.

PP8.00125 Magnetic field structure evolution in RMF plasmas , YURI PETROV, XIAOKANG YANG, TIAN-SEN HUANG, Prairie View A&M University — A study of magnetic field structure evolution during 40-ms plasma discharge had been performed in 80 cm long / 40 cm OD cylindrical chamber. Plasma current Ip$\sim$2–3 kA is produced by applied 500 kHz rotating magnetic field. In experiments, the 2D profile of plasma current is changed by feeding a 10-ms pulse current to additional magnetic coil located at the midplane. Using newly developed magnetic field pick-up coils system, we scanned the magnetic field in cross-section of plasma. Two experimental regimes were studied: without external toroidal field (TF), and with TF produced by applied axial current. When a relatively small current (<0.5 kA) is applied to the midplane coil, in both cases the total plasma current measured with Rogowski coil experiences a jump (up to 100%), but the profile of current remains almost unchanged. When a larger current (1–2 kA) is applied to the midplane coil, the total plasma current drops; the magnetic structure changes differently in two regimes. In regime without TF, the magnetic field of plasma current is reversed at R<a/2, so that two oppositely directed current layers are formed. In regime with TF, the plasma current first extends along Z, and then two rings of current are formed at the edge. At smaller radii, the current layer is still approximately uniform along Z. We also show how the magnetic field evolves during initial 1–3 ms transitional period of plasma formation.

PP8.00126 Studies of Inductively Sustained Compact Toroids in MRX, S.P. GERHARDT, E.V. BELOVA, M. YAMADA, H. JI, Y. REN, B. MCGEEHAN, C. JACOBSON, PPPL, M. INOMOTO, Osaka University — A central solenoid has been installed in the Magnetic Reconnection Experiment, in order to study the inductive sustainment of compact toroids (FRCs and spheromaks) formed from spheromak merging. Inductive sustainment applied to Argon FRCs extends the lifetime from $\sim$35μs to 350μs. The sustainment manifests itself as a balance between an inward pinch and resistive diffusion of flux and particles. In the configuration for these experiments, with neither strong plasma shaping nor nearby stabilizers, FRC sustainment in lighter gasses is difficult due the growth of co-interchange instabilities. The stability in Argon results from limited equilibrium field shaping, resistive diffusion, and finite-Larmour radius effects. When induction is applied to spheromaks, terminal tilt (Helium) or n=2 modes (Neon) typically develop. Induction applied to an Argon spheromak results in conversion to an FRC: the toroidal flux resistively decays while the poloidal flux is sustained by induction. The stability throughout the conversion is provided by resistive diffusion. These results will be related to the SPIRIT oblate FRC concept. Work supported by DOE.

PP8.00127 Occurrence of anomalous resistivity in the inductively current driven FRC, EIICHIROU KAWAMORI, Plasma and Space Science Center College of Science National Cheng Kung University, YASUSHI ONO, Graduate School of Frontier Sciences, University of Tokyo, TS GROUP TEAM — Occurrence of anomalous resistivity in the oblate FRC plasma was measured directly by magnetic probes in the center solenoid current drive (CSCD) experiment in TS-4. After the applied electric field by CSCD penetrated into the core region of the FRC, the resistivity of the FRC increased up to 10-20 times larger than the classical spitzer resistivity. It was found that the resistivity η at the magnetic axis scaled as $\eta \propto E$, where E is the electric field at the axis. This anomalous heating was the most probable cause for sustainment of the high-beta FRC under the preferential injection of magnetic energy by CSCD. The FRC plasma is concluded to have the robustness to self-adjust the plasma heating power depending on the magnetic energy injection.

PP8.00128 Overview and Recent Results from the ZaP Flow Z-Pinch[1], U. SHUMLAK, B.A. NELSON, C.S. ADAMS, D.M. CHAHIM, D.J. DEN HARTOG, R.P. GOLINGO, S.D. KNECHT, R. OBERTO, M. SYBOUTS, G. VOGMAN, Aerospace and Energetics Research Program, University of Washington — The ZaP Flow Z-Pinch investigates a magnetic confinement configuration that relies on sheared flow for stability in an otherwise unstable configuration. An axially flowing Z-pinch is generated with a coaxial accelerator coupled to a pinch assembly chamber. Magnetic probes measure fluctuation levels. Plasma is magnetically confined for an extended quiescent period where the mode activity is reduced. Doppler shift measurements of impurity lines show sub-Alfvenic, sheared flow during the quiescent period and low shear profiles during periods of high mode activity. The plasma has a sheared axial flow that exceeds the theoretical threshold for stability during the quiescent period and is lower than the threshold during periods of high mode activity. A holographic interferometer measures radially peaked density profiles during the quiescent period. Density profiles are analyzed to determine equilibrium profiles. Internal magnetic fields have been determined by measuring the Zeeman splitting of impurity emission. Measurements are consistent with a magnetically confined plasma. Plasma lifetime appears to be limited by neutral gas supply.

[1]This work is supported by a grant from DOE.

PP8.00129 Thomson Scattering Measurements on the ZaP Experiment, R.P. GOLINGO, U. SHUMLAK, B.A. NELSON, D.J. DEN HARTOG, University of Washington, THE ZAP TEAM — The ZaP Flow Z-Pinch Experiment is presently studying the effect of sheared flow on gross plasma stability. During a quiescent period in the magnetic mode activity, a dense Z-pinch with a sheared flow is observed on the axis of the machine. The velocity shear agrees with the threshold predicted by linear theory. A better comparison can be made once the pressure profile is known. A single point Thomson scattering system has been installed on the machine to directly measure the local electron temperature in the Z-pinch. The system has a 3 mm radial resolution and can collect scattered light up to 4 cm off of the axis of the machine. (The Z-pinch has a 1 cm characteristic radius.) The design and hardware allow for multipoint measurements that would measure the pressure profile of the Z-pinch. Initial testing showed the charge on the MCP was being depleted. Amplifiers for the MCP have been designed and are being characterized. The design of the system and initial results will be presented.

PP8.00130 Density Profile of the ZaP Flow Z-pinch Plasma using a 4-chord Interferometer, B.J. CHAN, U. SHUMLAK, B.A. NELSON, R.P. GOLINGO, University of Washington, ZAP TEAM[1] — The ZaP experiment focuses on the goal of generating a sheared flow stable Z-pinch plasma. This study investigates the density measurements of ZaP using a 4-chord, Mach-Zehnder configuration, heterodyne quadrature interferometer driven by a HeNe laser with a 632.8 nm wavelength. A single Bragg cell is used to split the laser beam and add a 40 MHz beat to the reference beam. The beams can be as close as 4 mm while the plasma has a 1 cm characteristic radius during the quiescent period. Radial density profiles along the z-axis can be determined using an Abel inversion technique. The axial variation of the plasma can also be determined by distributing the chords axially. These measurements will augment the temperature measurements made by the Thomson scattering system, helping to determine the Z-pinch pressure and current profiles. Experimental density measurements will be presented.

[1]Department of Aeronautics and Astronautics, University of Washington

PP8.00131 Results of the ZaP Flow Z-Pinch Inner Electrode Upgrade, SEAN KNECHT, URI SHUMLAK, RAYMOND GOLINGO, BRIAN NELSON, University of Washington, ZAP TEAM — The ZaP Flow Z-Pinch is a plasma physics experiment that investigates the stabilization of a plasma column using sheared flows. The experiment consists of a coaxial plasma accelerator coupled to a pinch assembly region. Recently, the 10 cm diameter inner electrode (cathode) of the experiment was replaced by a 15 cm diameter inner electrode with the goal of increasing the temperature of the pinch through adiabatic compression while also increasing the quiescent (stable) period of the plasma through increased control of neutral-gas injection. This increased control is a product of the larger number of neutral-gas puff valves located inside the inner electrode (eight in the present configuration, compared to one in the previous). Results obtained after this inner electrode upgrade will be presented. Special attention will be paid to the temperature, density, characteristic radius of the pinch and the length of the quiescent period. Comparisons will be drawn between the properties of the plasma when using the 10 cm inner electrode and the 15 cm inner electrode. Theoretical calculations have shown an increase in the temperature by a factor of two, a slight increase in number density and a decrease in the characteristic radius of the pinch. Plans for future efforts will also be reported.

PP8.00132 HBT-EP Kink Mode Control Research: Progress and Future Plans[1], G.A. NAVRATIL, B.A. DEBONO, J.M. HANSON, J.P. LEVESQUE, K.D. LITZNER, M.E. MAUEL, D.A. MAURER, T.S. PEDERSEN, D. SHIRAKI, J. BIALEK, A.H. BOOZER, O. KATSURO-HOPKINS, Columbia University, R. JAMES, U.S. Coast Guard Academy/Stevens Institute of Tech., S.F. PAUL, Princeton University — The High Beta Tokamak-Extended Pulse (HBT-EP) kink mode control research program is addressing critical key issues related to the suppression of the kink mode as a performance limiting instability of fusion devices. Current main research thrusts include: (i) studying advanced feedback control algorithms based on Kalman type filters, (ii) the installation of a new resistive wall and feedback coil set to measure ITER relevant internal control coil configurations and their effect on kink rigidity, and (iii) quantification of the role of neutral damping on resistive wall mode (RWM) dissipation mechanism physics using Li gettering to reduce charge exchange losses in the plasma edge. Recent experimental results on the effectiveness of a Kalman filter based feedback controller, design of the new segmented wall and small coverage control coils, a novel Li evaporator design, along with other diagnostic measurement improvements aimed at furthering our understanding of kink mode behavior will be reported and discussed.

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00133 A Kalman Filter for Feedback Control of Rotating External Kink Instabilities in a Tokamak Plasma[1]

J.M. HANSON, R. JAMES, M.E. MAUEL, D.A. MAURER, G.A. NAVRATIL, T.S. PEDERSEN, Columbia University — A Kalman filtering algorithm is proposed for feedback control of rotating external kink modes on the HBT-EP experiment. The Kalman filter contains an internal model that captures the dynamics of a rotating, growing mode. The filter actively compares the results of its model with real-time measurements to produce an optimal estimate for the mode's amplitude and phase. Numerical simulations using a model for the RWM consistent with experimental observations on HBT-EP show that Kalman filter feedback can suppress the unstable mode more quickly and with less control effort than less sophisticated controller algorithms. The Kalman filtering algorithm has been implemented on a set of low-latency, field-programmable gate array (FPGA) controllers and tested in closed-loop operation with RWM-unstable plasmas. Progress in using the Kalman filter to suppress unstable kink activity in HBT-EP plasmas will be reported.

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00134 Kink Radial Eigenmode Structure Measurements Using a Hall Sensor Array on the HBT-EP Tokamak[1]

D. SHIRAKI, J.M. HANSON, R. JAMES, D.A. MAURER, M.E. MAUEL, G.A. NAVRATIL, T.S. PEDERSEN, Columbia University — A 20 element, 4mm resolution Hall sensor array directly measures the poloidal field and its fluctuations in the edge region of HBT-EP plasmas and in the surrounding vacuum [1]. We describe the calibration of the probe, and discuss measurements of kink mode radial eigen-mode phase and amplitude structure measured in the edge plasma and in the vacuum region nearby a conducting wall. These Hall probe measurements are compared to theoretical predictions of the Fitzpatrick-Aydemir model of kink mode dynamics [2] to derive the RWM and plasma mode eigenvectors describing the measured external fluxes. The model accurately takes into account the presence of the segmented HBT-EP stabilizing wall using finite element VALEN code modeling calculations. In discharges with resistive wall mode (RWM) activity, the measured mode structure in the vacuum region given by the model is consistent with Hall sensor array measurements. The use of these measurements to quantify the magnitude of plasma dissipation affecting the RWM will be reported. [1] Y. Liu, *et al*, Rev. Sci. Instr. **76**, 9, 93501, 2005. [2] R. Fitzpatrick and A. Y. Aydemir, Nuc. Fusion, **36,** 11, 1996.

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00135 The Effects of Neutral Damping on Resistive Wall Mode Physics[1]

R. JAMES, US Coast Guard Academy/Stevens Institute of Tech., K. BECKER, Stevens Institute of Tech., J.M. HANSON, M.E. MAUEL, D.A. MAURER, G.A. NAVRATIL, T.S. PEDERSEN, Columbia University — The physics of the dissipation mechanism responsible for rotational stabilization of the resistive wall mode (RWM) continues to be an object of intense current research. On the High Beta Tokamak – Extended Pulse (HBT-EP), there is experimental evidence that edge neutral damping is a significant dissipation mechanism that affects tearing mode behavior [1]. To quantify the possible effect of neutral damping on RWM physics, we have constructed a 15-channel linear photo-detector array to measure Dα emission and its fluctuations. These measurements will be used in conjunction with a 1D space and 2D velocity kinetic transport model of the atomic and molecular deuterium penetration to quantify neutral profiles within the plasma [2]. Initial quantification of the neutral damping contribution to RWM rotational stabilization utilizing the measured Dα profiles to estimate the edge neutral density will be presented.

[1] E. D. Taylor, *et al.,* Phys. Plasmas **9**, 3938 (2002)
[2] B. LaBombard,MIT PSFC RR-00-9, (2000).

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00136 Design and Implementation of a Compact Lithium Evaporator to Minimize Edge Neutral Drag on the HBT-EP Tokamak[1]

D.A. MAURER, D. SHIRAKI, J.M. HANSON, R. JAMES, M.E. MAUEL, G.A. NAVRATIL, T.S. PEDERSEN, Columbia University — A candidate for the dissipation mechanism responsible for rotational stabilization of the resistive wall mode (RWM) on the HBT-EP tokamak is neutral damping via charge exchange reactions with cold Deuterium neutrals in the edge plasma. Lithium has been used successfully on the CDX-U experiment to substantially reduce recycling as a plasma fueling mechanism [1]. To study charge exchange drag and its effect on the RWM we have designed and plan to implement a small, compact Lithium evaporator that will getter neutral recycled Deuterium atoms to minimize the edge neutral population and as a result reduce charge exchange reactions. Evaporator design details, bench measurements of Li effusion rate performance, and plans for implementation of the evaporator during daily tokamak operation will be outlined.

[1] R. Majeski, *et al.,* Phys. Rev. Lett. 97, 7, 075002, 2006.

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00137 Real-Time Plasma Rotation Diagnostic for Measuring Small Doppler Shifts on the HBT-EP Tokamak

BRYAN DEBONO, JEREMY HANSON, ROYCE JAMES, DAVID MAURER, MICHAEL MAUEL, GERALD NAVRATIL, THOMAS PEDERSEN, Columbia University, STEVE PAUL, Princeton University — An optical fast time-scale toroidal velocity measurement has been developed for use on the HBT-EP tokamak [1,2]. A unique aspect of the measurement technique this diagnostic employs is that the Doppler shift is determined from the ratio of the light intensity from two detectors rather than by resolving the emission line with a traditional spectrometer. This is accomplished using an inexpensive, high-throughput measurement of impurity line emission using interference filters as the spectral device. One detector views the plasma through an interference filter whose passband has a negative slope, and the other views the identical volume of plasma through a positive-slope filter. The signal ratio varies as the emission line is Doppler shifted across the filter passbands. Importantly, the measurement technique is not sensitive to changes in plasma emission levels. For interference filters with a linear passband, the ratio is not sensitive to ion temperature, and the shifted He-II wavelength can be reduced to a simple function of the signal ratio, the channel's relative responsivity, and the two filters transmission curves. Diagnostic calibration procedures and edge plasma toroidal velocity measurements will be reported using a 10% Helium impurity seed in standard Deuterium discharges. Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00138 Thomson Scattering on the HBT-EP Tokamak[1]

J.P. LEVESQUE, K.D. LITZNER, J.M. HANSON, R. JAMES, D.A. MAURER, M.E. MAUEL, G.A. NAVRATIL, T.S. PEDERSEN, Columbia University — Thomson scattering can be used as a non-invasive method for measuring local electron density and temperature in plasmas. We describe the HBT-EP Thomson Scattering diagnostic, which is based on a design in use at DIII-D [1]. A five-channel interference filter polychrometer measures incoherent scattered light from an 8ns, 800mJ, 1064nm Nd:YAG laser pulse. A set of pre-amplification circuits designed by Princeton Scientific Instruments [2] has recently been installed for signal detection using avalanche photodiodes. System layout, alignment, and straylight level reduction techniques will be outlined. Rayleigh and Raman scattering calibration procedures have been used to absolutely calibrate the collection optics and detection system. Recent progress on diagnosing different HBT-EP plasmas using the Thomson scattering diagnostic will be presented.

[1] T. N. Carlstrom, *et al*, Rev. Sci. Instr. 61, 2858, 1990.
[2] D. Johnson, *et al*, Rev. Sci. Instr. 72, 1, 1129, 2001.

[1]Supported by U.S. DOE Grant DE-FG02-86ER53222.

PP8.00139 Helimak Turbulence and Simulation[1] , D. MIRACLE, J. FELKL, K. LEE, K.W. GENTLE, University of Texas at Austin, Fusion Research Center — The Helimak is a good realization of a sheared cylindrical slab with open field lines. The plasma is heated by microwaves at the electron cyclotron resonance. The resulting pressure and potential gradients give drift and fluid instabilities that drive fluctuations in density and potential. Simulations of the D'Ippolito-Krasheninikov equations show turbulence produced by a combination of Rayleigh-Taylor and Kelvin-Helmholtz instabilities. We compare the statistical properties of the turbulence in the simulation with the measured turbulence of the experiment. We present improvements to models used in codes to represent the physics of the Helimak more accurately. The two dimensional structures in density and floating potential are compared to those predicted by the simulation.

[1]Work supported by the Department of Energy Office of Fusion Energy Sciences DE-FG02-04ER54766

PP8.00140 Control of SOL Turbulence , KENNETH GENTLE, University of Texas at Austin, JAKUB FELKL, KEVIN LEE, DYLAN MIRACLE — The Helimak is an approximation to the infinite cylindrical slab, but the field configuration may be arranged as a simplified SOL with magnetic curvature and shear for realistic connection lengths. The turbulent amplitudes are typical of the SOL in fusion devices. Radially segmented isolated end plates allow application of radial electric fields that drive radial currents. Above a sharp threshold in applied voltage (driven current), the fractional turbulent amplitude is greatly reduced, as is the radial turbulent particle transport. Stabilization is observed for both positive and negative bias. Measurements of the transport reduction will be presented. The spatial relations between the region of applied fields and the turbulence suppression will be described. Extrapolation to fusion devices at higher density will be discussed. Work supported by the Department of Energy Office of Fusion Energy Sciences DE-FG02-04ER54766.

PP8.00141 Heavy Atom Neutral Beam Probe , ALVARO GARCIA DE GORORDO, GARY A. HALLOCK, KENNETH W. GENTLE, The University of Texas at Austin — A Heavy Neutral Beam Probe (HNBP) is being developed to measure the space potential on Helimak. The HNBP will make overlapping potential measurements with an array of Langmuir probes (LP). This will allow a direct comparison of LPs and our HNBP measurements. Helimak is a low temperature (7 to 10 eV) plasma device designed to study turbulence with relevance to fusion devices. Several diagnostic techniques were considered to probe this low temperature plasma. Two new techniques proposed involve photo-ionization of the probing beam, which may be singly ionized or neutral. The HNBP was selected however due to its compatibility with the turbulence measurements desired for Helimak. The primary species that we intend to probe with is sodium, which will be electrostatically accelerated to energies of 8 to 12 keV as an ion and subsequently neutralized. Much of the hardware for this system consists of the original Elmo Bumpy Torus (EBT) Heavy Ion Beam Probe (HIBP). The new photo-ionization techniques are ideal for low temperature nonmagnitized plasmas where continuous time resolution is not required, as in plasma processing of semiconductors.

PP8.00142 Drift-wave Turbulence in the Helimak[1] , KEVIN LEE, JAKUB FELKL, KENNETH GENTLE, DYLAN MIRACLE, Fusion Research Center, University of Texas at Austin — We present an experimental characterization of drift-wave turbulence in the Helimak, not only a finite realization of the sheared, cylindrical slab used in turbulence calculations, but also a good approximation for the SOL of a tokamak. Measurements of electrostatic turbulence are made both using an large fixed array of langmuir probes and a moveable array on a motorized probe drive. We examine such non-spatially oriented quantities as turbulence levels, fluctuation frequencies, and phases between density and electrostatic potential fluctuations. Measurements on dispersion relations and coherence lengths in both the radial and vertical directions are used to characterize the turbulence in the plane perpendicular to the magnetic field. In addition to this information, we also present a study of fluctuations parallel to the field lines, including measurements of parallel coherence lengths and parallel wavenumbers. Furthermore, we employ the use of wire coil probes to characterize fluctuations of both radial and vertical magnetic fields. We explore the relationships between density, potential, and magnetic turbulence.

[1]This work is supported by DOE-OFES grant DE-FG02-04ER54766.

PP8.00143 Simulations of extended MHD Turbulence and Sheared flows in the Helimak Configuration , RUSSELL B. DAHLBURG, Naval Research Laboratory, JEAN C. PEREZ, University of Wisconsin-Madison, WENDELL HORTON, The University of Texas at Austin — We investigate the interaction of sheared plasma flows with the ambient turbulence in the Helimak configuration using a magnetohydrodynamic slab model that captures most of the important features present in the Helimak device at the University of Texas. We report 2D and fully 3D nonlinear simulations using magnetic and flow profiles based on experimental data. The experiment is well modeled as a bounded magnetized jet. The extended MHD model includes a gravitational term to account for magnetic field curvature drifts. Important features of the code include the presence of walls, resistivity and viscosity. The nonlinear development of various disturbances will be discussed. Preliminary results show that as the linear modes attain finite amplitude, there is considerable development of multiscale plasma excitation.

PP8.00144 First Flight of the Levitated Dipole Experiment[1] , D.T. GARNIER, M.E. MAUEL, Columbia University, A.C. BOXER, J.E. ELLSWORTH, J. KESNER, MIT Plasma Science and Fusion Center — In the past year, the first levitated experiments have been conducted in the Levitated Dipole Experiment (LDX). LDX, which consists of a 560 kg superconducting coil floating within a 5m diameter vacuum chamber, is designed to study fusion relevant plasmas confined in a dipole magnetic field. In previous plasma run campaigns, conducted with the dipole coil held by thin supports, stable high beta plasma operation were demonstrated where the plasma kinetic energy is contained in population of energetic particles. It is expected that levitated experiments will improve confinement by removing the primary loss of energy and particles along field lines. This in turn will lead to higher plasma density and broader radial profiles which should increase the stable operational space. In February, the first flight of the floating dipole coil was achieved with 40 minutes of continuous levitation and three demonstration plasma shots. This first flight experiment demonstrated the operation of the digital feedback system that provides for stable levitation of the coil. The results from the first plasma experiments, planned for early fall, will be presented.

[1]Supported by US DOE Grants: DE-FG02-98ER54458/9.

PP8.00145 Prospects for Driven Particle Convection Tests in LDX[1] , M.E. MAUEL, D.T. GARNIER, Columbia University, A.C. BOXER, J.E. ELLSWORTH, J. KESNER, MIT PSFC — An attractive consequence of the shear-free magnetic field of levitated dipole confinement devices is the possibility of using advanced fusion fuel cycles [Kesner et al., NF 44(2004)193]. When the pressure and density profiles are isentropic, convective interchange mixing transports particles but does not necessarily transport heat. In shear-free magnetic fields, low-frequency convective circulation is interchange-like and the size scale of the largest circulation motion extends to fill the confinement volume. As a consequence, particles may be convected from the hot central region to the edge in times much less than the energy confinement time. One goal of the Levitated Dipole Experiment (LDX) is to investigate the relative energy and particle time scales and also to explore active means to induce rapid particle circulation that do not alter the dipole's highly peaked, and isentropic, pressure profiles. Experiments that are planned include the following: (1) optical measurement of localized density and impurity transport, (2) flux-tube charging with insertable bias probes, (3) the impact of localized field errors on convective cell formation, and (4) the application of a weak toroidal field to limit the radial extent of convection and prevent inward particle transport to the dipole magnet.

[1]Supported by US DOE Grants: DE-FG02-98ER54458/9.

PP8.00146 Low Frequency Fluctuations in the Levitated Dipole Experiment[1] , J. KESNER, A. BOXER, J.E. ELLSWORTH, MIT PSFC, D.T. GARNIER, M.E. MAUEL, Columbia University — Plasma that is heated by ECRH can be subject to instability that feeds on the free energy of either the hot component or the thermal plasma component. A closed field line confinement system such as a levitated dipole is shear-free and the plasma compressibility provides stability. Theoretical considerations of thermal plasma driven instability indicate the possibility of MHD-like behavior of the background plasma, including convective cell formation and drift frequency (entropy mode) fluctuations. In experiments in LDX (in the supported mode of operation) we create a two-component plasma in which a thermal species contains most of the density and an energetic electron species contains most of the plasma stored energy. In addition to high frequency fluctuations reported elsewhere [Garnier et al., PoP 13(2006)56111] we observe low frequency fluctuations in the kHz range that presumably are driven by the thermal species. The fluctuations become undetectable during strong edge fueling when the density profile broadens. During levitated operation lower fueling rates are required and we will compare the low frequency activity between the levitated and supported modes of operation.

[1]Supported by US DOE Grants: DE-FG02-98ER54458/9.

PP8.00147 Density Profile Dynamics in the Levitated Dipole Experiment[1] , A.C. BOXER, J. KESNER, J.L. ELLSWORTH, MIT Plasma Science and Fusion Center, D.T. GARNIER, M.E. MAUEL, Columbia University — Measuring and understanding the evolution of the plasma density is an important goal for the Levitated Dipole Experiment (LDX). Theoretical considerations suggest that the density may naturally develop a highly peaked profile characterized by an equal number of particles per flux-tube: $\delta(nV) \sim 0$, where $V \equiv \oint \delta\ell/B$. Accordingly, in a dipole-confined plasma, the density profile is predicted to vary with radius as $n \sim 1/r^4$. A 4-cord microwave-interferometer density diagnostic with a center frequency of 60 GHz has been built and tested. In experiments where the dipole was not levitating but rather suspended by thin supports, the density profile was observed to respond to (1) ECRH frequency, (2) total ECRH power, and (3) neutral gas fueling. Comparison with data from true levitation experiments (Sept. 2007) will allow us to further characterize the density profile dynamics of dipole-confined plasmas.

[1]Supported by US DOE Grants: DE-FG02-98ER54458/9

PP8.00148 Strong, Nonaxisymmetric Flows Driven in a Dipole Confined Plasma[1] , M.W. WORSTELL, B.A. GRIERSON, M.E. MAUEL, Columbia University — Previous studies using the Collisionless Terella Experiment (CTX) have shown plasma dynamics to be dominated by interchange mixing. We report the first results of a larger study to investigate the controlled excitation of particular interchange modes, the nonlinear coupling of these modes, and the effect of driven excitation on plasma convection and transport. In CTX, a large diameter electrostatic probe is inserted at various radii and excites strong, nonaxisymmetric flows by flux-tube charging and driving nonaxisymmetric cross-field currents. We have applied both positive ($\sim$ 10 V) and negative ($\sim$ -1000V) biases. Negative bias has been applied to lower-density plasma, which are dominated by the Hot Electron Interchange (HEI) modes, and to the high density regime dominated by turbulent fluctuations. As an extension of a recently implemented simulation upgrade (see accompanying poster) results including a bias probe will be displayed. We also describe plans for our next step investigations when multiple bias probes will be driven by frequency and phase controlled power supplies to excited resonant, rotating interchange modes.

[1]This work is supported by U.S. DOE Grant DE-FG02-00ER54585.

PP8.00149 Simulating Interchange Turbulence in a Dipole Confined Plasma[1] , B.A. GRIERSON, M.W. WORSTELL, M.E. MAUEL, Columbia University — The dipole magnetic field is a simple, shear-free configuration. Strong, low-freqency interchange mixing, with $k_{\parallel} = 0$, allows plasma cross-field dynamics to be 'bounce-averaged'. When dipole confined plasma is produced with ECRH, fast Hot Electron Interchange (HEI) instabilities appear at low densities, and lower-frequency turbulent fluctuations occur at higher densities. The global mode structure of the HEI and centrifugal interchange are understood, with good agreement between laboratory measurements and nonlinear simulations. However, the turbulent fluctuations are much less understood. They exhibit a power-law like spectrum, and require a spatially refined computational grid. To study the interchange turbulence, a fully parallel simulation has been developed to examine these fluctuations. The simulation includes a distributed Fast-Poisson solver for the ion polarization drift, a particle source and sink, as well as user-inputs to charge individual flux tubes driving interchange mixing. Results of high-resolution simulations and parallel performance will be given.

[1]This work is supported by U.S. DOE Grant DE-FG02-00ER54585.

PP8.00150 Linear Study of Electromagnetic Hot Electrons Instabilities in a Closed Field Line Plasma. , NATALIA KRASHENINNIKOVA, LUIS CHACON, LANL, JAY KESNER, PSFC (MIT) — Motivated by the electron cyclotron heating being employed on the Levitated Dipole Experiment, the hot electron instabilities are investigated by considering the simplest closed magnetic field line geometry - a Z-pinch. The linear theory of electromagnetic interchange modes in a plasma of fluid background and a small fraction of kinetic hot electrons was recently studied theoretically [1]. The model assumed that the species diamagnetic drift and magnetic drift frequencies are of the same order, and that the wave frequency is much larger than the characteristic frequencies of the background but much smaller than that of the hot species. We extend the framework outlined in this reference to allow mode frequencies of the same order as typical hot electron frequencies, and relax the large azimuthal wave number and local approximations. The characteristic equation, resulting from the eigenvalue formulation is a highly non-linear, integro-algebric function, and is handled in this work by a fast 1-D generalized Newton-based eigenvalue solver. This tool allows us to study the evolution of the mode frequency as a function of several parameters, such as the background profile steepness and the hot electron fraction. The results are discussed and compared with both theoretical predictions1 and experimental results. [1] N. Krasheninnikova, P. J. Catto, Phys. Plasmas, 12, 32101 (2005).

PP8.00151 Improved Plasma Properties in RT-1 with a Levitated Coil , HARUHIKO SAITOH, ZENSHO YOSHIDA, YUICHI OGAWA, JUNJI MORIKAWA, SHO WATANABE, YOSHIHISA YANO, JUNKO SUZUKI, The University of Tokyo — Ring Trap-1 (RT-1) is a novel device to confine plasmas in a magnetosphere-like configuration generated by a superconducting internal conductor. The ring coil is excited with a permanent current of I_c=250kAT that is magnetically levitated in the chamber to minimize disturbances to the plasmas. The main scientific objective of RT-1 is to realize self-organized states of flowing plasmas with a very high beta value, where the thermal pressure of plasmas is balanced by the hydrodynamic pressure of a fast flow (S. M. Mahajan & Z. Yoshida, PRL **81**, 4863 (1998), Z. Yoshida & S. M. Mahajan, PRL **88**, 095001 (2002)). We have started a series of initial plasma experiments since 2006, and in this study, we focused on the improvements of plasma properties by the coil levitation. Hydrogen plasmas were generated by an 8.2GHz ECH system. When the coil was levitated, a line integrated electron density increased to n_e=4x10^{17}m^{-2} and the peak density was close to the O-mode cut off density of the microwave. The beta value of the plasma was $\sim$3% and the pressure was mainly sustained by a high energy component of electrons. The magnetic surface configuration of RT-1 is also suitable for the confinement of non-neutral plasmas. Experiments on electron plasmas were conducted in RT-1 expanding the previous work in a normal conducting device.

PP8.00152 Wave-induced Helicity Current Drive by Helicon Waves , MANASH KUMAR PAUL, Institute for Plasma Research, Bhat, Gandhinagar-382428, India — Investigation of helicity in the dynamo field components of helicon wave, lead to a novel study of wave induced helicity current drive in helicon wave generated plasma. Helicon discharge, produced in a toroidal vacuum chamber of small aspect ratio, shows strong poloidal asymmetry in the wave magnetic field components. Owing to this strong poloidal asymmetry in the wave magnetic field structures, a nonresonant current is driven in plasma by the dynamo electric field, which arise due to the wave helicity injection by helicon waves. Simultaneous rise in wave helicity is observed when the input RF power is increased. Study of parametric dependence of plasma current in very high frequency operating regime, along with numerical estimations of nonresonant components, has been done. Close agreement between the numerical estimations and the experimentally obtained plasma current magnitudes clearly delineates the plasma current due to wave-induced helicity from other possible resonant or nonresonant sources at present parameter regime. Preliminary results of helicon current drive experiments and comparison with the numerical estimations are presented.

Wednesday, November 14, 2007 2:00PM - 5:00PM –

Session PM4 Mini-conference on Angular Momentum Transport in Laboratory and Nature IV

Rosen Centre Hotel Salon 1/2

2:00PM PM4.00001 Angular Momentum Transport in the Earth's Core , BRUCE BUFFETT, University of Chicago — Convection in the Earth's liquid iron core continually regenerates the geomagnetic field and sustains a differential rotation between the inner and outer boundaries. The differential rotation is thought to be a consequence of large-scale fluid circulation in a region defined by the tangent cylinder (a hypothetical cylinder that is tangent to the solid inner core at the equator). Magnetic stresses sweep the solid inner core in the direction of the overlying flow. An additional complication arises due to gravitational interactions between the solid inner core and the rocky outer region, known as the mantle. A heterogeneous distribution of mass in the inner core and mantle can yield a surprisingly large gravitational force when the inner core rotates away from its equilibrium alignment with the mantle. This restoring force is sufficient to oppose the magnetic stresses that drive inner-core rotation. However, the inner core can escape the lock of gravity by plastically deforming as it rotates. Numerical dynamo models that include the influences of gravitational coupling and plastic deformation suggest that the differential rotation is limited by the rate of deformation of the inner core. The calculations also predict large fluctuations in the rate of differential rotation. Any angular misalignment between the inner core and mantle transfers angular momentum to the mantle, which can be detected as a change in the length of day. The fluctuations in inner-core rotation also excite waves that transmit angular momentum through the liquid core.

2:30PM PM4.00002 Angular momentum transport in cylindrical and spherical Couette flows[1] , DANIEL LATHROP, University of Maryland — Cylindrical and spherical Couette flows (flows between differentially rotating cylinders and spheres) are simple geometries for understanding turbulent transport. I'll review experiments at high Reynolds number of turbulent flows in water, glycerin-water solutions, and liquid sodium. Instabilities can occur on top of relatively featureless turbulence due to restoring forces such as Lorentz forces, Coriolis forces or gravity waves on a free surface. The former shares some characteristics with the Magnetorotational instability. The latter cases speak to perhaps a general ability of turbulent shear flows to drive large scale oscillations when there exist near-neutral oscillatory modes.

[1]This research was supported by the National Science Foundation.

3:00PM PM4.00003 Understanding the Uniform Rotation of the Solar Radiative Interior , TAMARA ROGERS, HAO/NCAR — Two models exist to explain the relatively uniform rotation of the solar radiative interior; one magnetic in nature and one purely hydrodynamic. In this talk I will discuss the strengths and weaknesses of both models. I will then focus on the currently favored magnetic model and discuss recent research which may be able to address previous weaknesses of this model.

3:30PM PM4.00004 Angular Momentum Transport in the Solar Tachocline , STEVEN TOBIAS, University of Leeds — The eleven year solar activity cycle is believed to be generated by a dynamo. The solar tachocline is a region of strong differential rotation located at the base of the solar convection zone, which is believed to play a crucial role in the operation of this dynamo. The dynamics of the shear layer is however poorly understood. Indeed there is no consistent theory available for the existence of such a thin tachocline. The problem of tachocline existence is inherently linked to that of instabilities and angular momentum transport in stably stratified magnetised collisional plasmas. In this talk I shall review the theory for this and discuss some ideas for future progress in this area.

4:00PM PM4.00005 Magnetized Accretion Disk Corona[1] , DMITRI UZDENSKY, JEREMY GOODMAN, Princeton University — We present a statistical description of a force-free magnetic field in the corona above a turbulent accretion disk. The field is represented by a statistical ensemble of loops tied to the disk. Each loop evolves under several physical processes: Keplerian shear, turbulent random walk of the disk footpoints, and reconnection with other loops. To build a statistical description, we introduce the distribution function of loops over their sizes and construct a kinetic equation for this function. This Loop Kinetic Equation is similar to Boltzmann's kinetic equation, with reconnection described by a binary collision integral. We solve the equation numerically and obtain a statistical steady state. This allows us to calculate self-consistently the distribution of magnetic pressure with height, the equilibrium shapes of loops of different sizes, and the energy associated with a given loop. We then assess the effectiveness of the coronal magnetic field in transporting angular momentum across the disk and also calculate the energy- and height-distribution of coronal reconnection events.

[1]Work supported by NSF Center for Magnetic Self-Organization

4:15PM PM4.00006 Analytical theory of the PDFs of momentum transport and the formation of shear flow in plasmas , JOHAN ANDERSON, EUN-JIN KIM, Sheffield University — There has been overwhelming evidence that coherent structures play a critical role in determining the overall transport in a variety of systems. A crucial question in momentum transport theory is thus the prediction of the PDFs of the momentum transport due to these structures and of the formation of shear flow. Here, we report on a first analytical result on these two closely related problems by using a novel non-perturbative method. We first compute the PDF tails of global momentum flux in the ion-temperature-gradient turbulence, by assuming that a short-lived modon is a coherent structure responsible for bursty and intermittent events, contributing to the PDF tails. The tail of PDF of global momentum flux $R = \langle v_x v_y \rangle$ is shown to be exponential with the form $\exp\{-cR^{3/2}\}$, which is broader than a Gaussian, similarly to what was found in the previous local studies [1-2]. The non-Gaussian tail is a manifestation of intermittency due to rare events. The overall amplitude of the PDFs crucially depends on the temperature and density scale lengths through the constant c. We then present a consistent theory of the PDFs of the formation of a shear flow by incorporating its generation via the computed momentum flux. Implications for momentum transport in astrophysical plasmas will be addressed. 1 E. Kim and P. H. Diamond, Phys. Rev. Lett. 88 225002 (2002) 2 E. Kim et al, Nucl. Fusion 43 961 (2003)

4:30PM PM4.00007 Experimental Verification of Braginskii's Viscosity in MHD Plasma Jet of Reconnection Scaling Experiment. , L. DORF, X. SUN, T. INTRATOR, J. HENDRYX, G. WURDEN, I. FURNO, G. LAPENTA, (LANL) — Braginskii's theory gives a simple and useful expression for ion-ion viscosity in magnetohydrodynamic (MHD) plasmas. While this formula has been used extensively, no experimental verification of it can be found in the literature. A few direct measurements of Fokker-Plank diffusion coefficients have been reported, but ion viscosity has not been recognized in those works. This talk will describe the first experimental evaluation of ion viscosity, performed by measuring and comparing the terms of the MHD momentum balance equation. Namely, time-dependent, 2D profiles of the axial flow velocity, density, electron temperature, and magnetic field components were measured at two axial locations in a plasma column of the Reconnection Scaling Experiment. Significant plasma flow with the velocity on the order of the ion acoustic speed was detected, with the velocity decreasing downstream. The results show that the ion momentum flux is dissipated by the ion-ion viscosity due to a significant radial shear of the axial velocity. Chord-integrated ion temperature measurements performed at several radial locations using Doppler broadening spectroscopy show temperature of about 1eV. Comparison of the measured viscosity with Braginskii's predictions demonstrates a good agreement. Supported by OFES, and DOE/LANL contract DE-AC52-06NA25396.

4:45PM PM4.00008 Supersonic radiatively cooled rotating flows and jets produced by wire array z-pinches[1] , D.J. AMPLEFORD, Sandia National Laboratories , A. CIARDI, Observatoire de Paris, S.V. LEBEDEV, S.N. BLAND, S.C. BOTT, Imperial College London — A modification of the wire array z-pinch is used to produce a rotating shock and jet in the laboratory. The wires in a wire array z-pinch undergo a steady ablation as the Lorentz force acts to accelerate plasma from the wire cores, which remain stationary, towards the array axis. In a twisted conical array both a radial component to the current and an axial component to the magnetic field are present, which provides an azimuthal component to the Lorentz force (in addition to axial and radial components). These streams collide on axis, however both the angular and axial momentum are conserved in the standing conical shock which is formed. The presence of angular momentum leads to a shock with large diameter and hollow mass profile. A jet is accelerated out of the top of the conical shock. This jet has a high degree of radiative cooling, retains angular momentum and also has a hollow density profile.

[1]Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US DOE's NNSA under contract DE-AC04-94AL85000.

Wednesday, November 14, 2007 2:00PM - 4:20PM –

Session PM5 Mini-conference on the First Microns of the First Wall: Lithium Coatings and Surfaces Rosen Centre Hotel Salon 11/12

2:00PM PM5.00001 Lithium and Deuterium on NSTX Carbon Tiles[1] , WILLIAM R. WAMPLER, Sandia National Laboratories, CHARLES H. SKINNER, HENRY W. KUGEL, Princeton Plasma Physics Laboratory — Evaporation of lithium onto the wall of NSTX has produced significant improvements in plasma conditions. The effect of this lithium on plasma-wall interactions is expected to depend mainly on its concentration near the surface of plasma-facing components. Here we report measurements of the concentration of lithium and deuterium (D) versus depth on 21 carbon tiles removed from NSTX after lithium deposition experiments in 2006. Measurements were done using nuclear reaction analysis. The lithium was observed to be within a few microns of the surface, which shows that diffusion of lithium into the carbon was less than a few microns. Lithium coverage was an order of magnitude lower on tiles shadowed from the lithium evaporation source than on unshadowed tiles at similar poloidal positions, whereas the D coverage was similar. This shows that the D coverage was not greatly changed by the lithium deposition. The D coverage was highest in the private flux region between inner and outer strike points of the high triangularity plasmas used. The presence of lithium at the strike points shows that it had not been removed by plasma erosion at these high flux locations.

[1]Sandia is operated by Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

2:20PM PM5.00002 The lithium deposition on NSTX plasma facing components by LITER-1 evaporator in 2006[1] , LEONID E. ZAKHAROV, HENRY KUGEL, LANE ROQUEMORE, CHARLES SKINNER, Princeton University, PPPL — The deposition of lithium from the LITER-1 lithium evaporator to the in-vessel components of NSTX during the 2006 experimental campaign has been calculated using the recently written Cbebm code. Its numerical model represents a collisionless gas model which assumes re-evaporation of the Li molecules after their collision with the hot walls of evaporator. Theoretically, the model is valid up to lithium temperatures of 650 °C. The code reproduces the real 3-D geometry of the evaporator canister and snout as well as the plasma facing components of NSTX, including the details of its carbon tiles. The simulation data can serve as a reference Li deposition distribution, which would be established in a perfectly clean vacuum vessel, and are compared with the lithium content in the surface layer of the sample tiles, obtained by Bill Wampler (SNL) using nuclear analysis.

[1]Supported by US DoE contract No.DE–AC020–76–CHO–3073.

2:40PM PM5.00003 Surface analysis of lithium coatings in NSTX[1] , J. TIMBERLAKE, H.W. KUGEL, C.H. SKINNER, Princeton Plasma Physics Laboratory, N. YAO, Princeton University PRISM Imaging and Analysis Center — Lithium coatings have been applied to NSTX plasma facing surfaces as part of a long term program to explore the potential for lithium to improve plasma and PFC performance. A LIThium EvaporatoR (LITER) directed a collimated stream of lithium vapor from an upper vacuum vessel port toward the graphite tiles of the lower center stack and divertor either before, or continuously between and during, discharges. Silicon witness coupons and other samples were retrieved from the vacuum vessel after the campaign and the surface morphology and elemental compostion examined with a XL30 FEG-SEM microscope equipped with an energy dispersed X-rays system sensitive to elements with atomic number greater than 4. The surfaces showed a complex morphology with nucleation sites apparent. Carbon and oxygen were the dominant impurities. Trace metals (Fe and Cr) were detected in the coating on the Si coupon, but not in a flake of bulk Li. We will present results of the surface analysis of samples exposed to Li evaporation in NSTX.

[1]Support is provided by the U.S. DOE Contract No. DE-AC02-76CH03073.

3:00PM PM5.00004 Mass changes in NSTX surface layers with Li conditioning as measured with quartz microbalances[1] , C.H. SKINNER, H.W. KUGEL, A.L. ROQUEMORE, Princeton Plasma Physics Laboratory — Three quartz crystal microbalances are deployed in plasma shadowed areas in NSTX at the upper and lower divertor and outboard midplane. Pulse-by-pulse material gain and loss (dynamic retention) is measured with a sensitivity of a fraction of an atomic monolayer. At the time of a plasma discharge a transient increase in mass of order 0.1 μg/cm^2 is seen. This decays in the interpulse period to a level either higher, lower or similar to that prior to the discharge. Following a days plasma operations a loss in mass is observed over several hours that parallels the deuterium outgassing. For the first discharge of the day, the relatively unsaturated hydrocarbon layer shows a step-up in mass independent of plasma conditions. In 2007 lithium was evaporated onto plasma facing components to control recycling. We will present data on the mass changes of surface layers with and without lithium coatings.

[1]Support is provided by the U.S. DOE Contract No. DE-AC02-76CH03073.

3:20PM PM5.00005 In-situ elemental and chemical state characterization of lithiated surfaces under energetic particle bombardment.[1] , JEAN-PAUL ALLAIN, S. HARILAL, M. NIETO, M.R. HENDRICKS, AHMED HASSANEIN, Argonne National Laboratory, PPPL COLLABORATION[2], SNLL COLLABORATION[3] — Lithium has been considered a potentially viable plasma-facing surface enhancing the operational performance of fusion devices such as: TFTR and NSTX. Solid and liquid lithium has been studied extensively both in its erosion and hydrogen-retaining properties. However, questions still remain on the role of lithiated surfaces and multi-material interactions at the plasma edge. Lithiated surfaces include: liquid Li on metal substrates, Li alloys and Li coatings. The main processes studied here (e.g. erosion, H-retention) consist of spatial scales from a few monolayers at the vacuum/film interface to 100's nm deep. Techniques used include: low-energy ion scattering spectroscopy (LEISS), direct recoil spectroscopy, X-ray photoelectron spectroscopy and in-situ erosion diagnosis. LEISS diagnoses the first 2-3 monolayers. XPS gives chemical state data 10-nm into the lithiated surface. Three cases are presented in this paper: liquid Li, alloyed Li and Li coatings under D irradiation.

[1]Work supported in part under Contract No. DE-AC02-06CH11357

[2]C. Skinner, H. Kugel, R. Majeski, R. Kaita

[3]R. Bastasz and J.A. Whaley

3:40PM PM5.00006 Physical sputtering and chemical erosion studies on plain and lithiated graphite samples , RAMASAMY RAJU, MARIN RACIC, J. LEE, DAVID RUZIC, University of Illinois at Urbana-Champaign, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM — PFC candidate materials must have characteristics allowing for high temperature resilience while limiting deuterium recycling and core contamination from erosion. Graphite is a good choice of material for its high temperature tolerance. However, to reduce deuterium recycling issues of the graphite surface, lithium has been used extensively as a coating on PFC surfaces, though many issues on physical and chemical sputtering still remain. The Ion-surface InterAction Experiment (IIAX) measures the absolute, angular-resolved and self-sputtering yields of many particle/target combinations. Baseline sputtering yield of an untreated ATJ graphite sample is very close to the predicted TRIM estimates with an average of 0.06 +/- 0.02 atoms / ion. Preliminary experiments show that Li was evaporated and deposited with thickness of 320 nm on a Si wafer. Li deposition on a ATJ graphite sample was verified using scanning electron microscopy. Chemical sputtering analysis on a ATJ graphite sample is done, and results confirm the operation of the RGA. Trail experiments on relative levels of Li to C collected during sputtering are analyzed using TOF-SIMS. A deposition rate of 10 nm/min is the most relevant to NSTX. Additional experiments using varying thicknesses and deposition rates of Li are described.

4:00PM PM5.00007 Liquid lithium self-propulsion under applied heat loads , MICHAEL JAWORSKI, CHEUK LAU, MADISON MALFA, DAVID URBANSKY, DAVID RUZIC, University of Illinois at Urbana-Champaign, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN TEAM — Recent experiments have lead to a resurgence in interest in liquid lithium plasma facing components (PFCs). Current plans on NSTX are to implement a Liquid Lithium Divertor (LLD) in the device. This system will utilize a porous metal foam with a thin layer of liquid lithium in contact with the divertor plasma. The liquid-solid system is examined and thermocapillary and thermoelectric magnetohydrodynamics (TEMHD) are deemed important effects. Thermocapillary forces were observed on the CDX-U device redistributing a point source heat load. In NSTX, these forces are expected to create a surface velocity on the order of 7cm/s for a 1mm layer. TEMHD may create additional forces on the liquid metal system. In the case of porous media, the capillary pumping may affect both TEMHD and thermocapillary induced flows. In order to accurately assess the power handling and particle pumping capabilities of liquid lithium PFCs, all these effects will need to be taken into account. The SLiDE apparatus has been designed in order to test thermocapillary and TEMHD flows with an incident heat flux in a laboratory scale environment. An overview of these effects in addition to results of liquid lithium imbibition experiments in a porous metal foam are shown.

Wednesday, November 14, 2007 3:00PM - 5:00PM –

Session QI1 Fast Ignition I Rosen Centre Hotel Junior Ballroom

3:00PM QI1.00001 Fast ignitor target studies for HiPER[1] , STEFANO ATZENI[2], Dipartimento di Energetica, Università di Roma La Sapienza and CNISM, Italy — Recently, a European collaboration has proposed the HiPER facility [1], aimed at the demonstration of laser driven inertial fusion fast ignition. According to the present design, HiPER will have a 3ω, multi-beam, multi-ns-pulse of about 250 kJ and a 2ω or 3ω ignition beam delivering 70 kJ in about 15 ps. In this talk, we present studies on fast-ignitor targets directly driven by 100-300 kJ compression pulses, followed by 70-100 kJ ignition pulses. First, we discuss ignition and compression requirements, and present gain curves, based on a model including ablative drive, compression, ignition and burn, and taking the coupling efficiency η_{ig} of the igniting beam as a parameter. It turns out that ignition and moderate gain (up to 100) can be achieved, provided that adiabat shaping is used in the compression and the efficiency η_{ig} exceeds 20%. According to present understanding, a 2ω ignition beam is required to make the hot-electron range comparable to the desired size of the hot spot. A reference target family is then presented, based on 1-D fluid simulation of compression, and 2-D fluid and hybrid simulations of fast electron transport, ignition and burn. The sensitivity to compression pulse shape, as well as to hot-electron source location, hot electron range and beam divergence is also discussed. Models and perturbation codes have been used to study the Rayleigh-Taylor instability. Crucial issues that have so far not been studied in detail include high convergence cone-guided implosions, the generation of the hot electron beam and its transport in low-to-moderate density plasmas. However, we have begun studying the hydrodynamics of cone-guided targets with model hydrodynamics simulations and we are tackling aspects of intense laser interaction, hot electron generation and transport with PIC codes. [1] M. Dunne, Nature Phys., **2**, 2 (2006); HiPER Technical Design Report: http://www.hiper-laser.org/overview/TDR/tdr.asp

[1]Supported in part by the Italian projects PRIN 2005029572 and FIRB RBNE03N48B BLISS.

[2]In collaboration with C. Bellei, J. R. C. Davies, R. G. Evans, J. Honrubia, X. Ribeyre, G. Schurtz, A. Schiavi, J. Breil, J. L. Feugeas, L. Hallo, P. H. Maire, J. Meyer-ter-Vehn, P. H. Nicolai, M. Olazabal, L. Silva, G. Sorasio and V. T. Tikhonchuck.

3:30PM QI1.00002 Control of the Fast Electron Beam Divergence for Fast Ignition Inertial Fusion , PETER NORREYS, STFC Rutherford Appleton Laboratory — The fast electron beam divergence in intense laser-plasma interactions is a vital ingredient in determining the success of fast ignition inertial fusion. If it is too large, then the short pulse laser energy required to generate the temperatures needed for hot spark formation becomes impractical to implement on ignition scale facilities. In this talk, I will review the recent experiments performed on the Vulcan PW laser facility to investigate this question. The pulse duration was changed from 0.5 ps - 10 ps and a wide range of plasma diagnostics were fielded. An intensity dependence to the beam divergence has been identified for the first time from these measurements. Two dimensional particle-in-cell simulations reproduce this effect. I will present new ideas on how the divergence can be controlled and the fast electron transport collimated. These are supported by analytic theory and validated by hybrid Vlasov-Fokker-Planck and hybrid particle-in-cell modeling.

4:00PM QI1.00003 Intense Laser Plasma Interactions on the Road to Fast Ignition[1] , LINN VAN WOERKOM, Ohio State University

— Successful Fast Ignition (FI) offers the prospect of reduced laser driver energy and greater energy gain, which enhances the possibilities for realistic Inertial Confinement Fusion (ICF) energy power plants. The interaction of high intensity laser pulses with hot dense plasma lies at the core of the FI concept. At the most basic level FI relies on converting high energy, high intensity laser light into a beam of electrons which must propagate for 10's to ∼100 microns and deposit their energy in the compressed fuel. Thus, the process may be divided into two critical processes: 1) the generation of energetic electrons from the laser-matter interaction, and 2) the transport of energetic electrons through hot dense plasma. Experiments to date have only explored part of the FI relevant parameter space concerning laser energy, intensity, pulse duration, and transport of MeV particles. With the approach of first light on OMEGA EP and then NIF ARC, the field is poised to make crucial measurements that will determine the requirements for full scale FI. This talk will present recent results from high intensity laser-cone interactions that help pave the way to the next generation of experiments.

[1]This work was performed under the auspices of the U.S. Dept of Energy on contracts DE-FG02-05ER54834, DE-FG02-00ER54606 and W-7405-Eng-48

4:30PM QI1.00004 Hot electron energy coupling in cone-guiding fast ignition[1] , YASUHIKO SENTOKU, University of Nevada, Reno

— A critical issue for the fast ignition of inertial fusion targets, where compressed fuel is ignited by injection of an intense short laser pulse, is whether the hot electrons produced in the interaction are in an energy range conducive to efficient heating of the core. The required in-tensity of the ignition laser light becomes greater than 10^{20} W/cm^2 to meet the ignition condition. In this talk, we present the result of a "numerical" experiment of Cone Guided Fast Ignition with a super-intense laser pulse using a collisional PIC code, $PICLS$ and challenge this critical issue. Our numerical experiment is the first simulation, which evaluates the complete physics underlying FI self-consistently, excluding nuclear reactions. In particular, this simulation accounts for hot electron generation, fast ion acceleration, energy transport in large density scale coronal plasmas, and collisional energy coupling to the core, i.e. we study a model situation that is as comprehensive and self-consistent as possible today. We found that the while electromagnetic instabilities appear around the cone target where the plasma density is less than a few hundred times critical density, no significant fields are found near the core. This indicates that core heating is mainly provided by collisional processes. In particular, the predominant core heating mechanism has been identified as drag heating between hot and bulk electrons. We also found that after the preplasma inside the cone was blown away, the hot electron temperature observed in the simulation is lower than the ponderomotive scaling. A simple analytic scaling law for the hot electron temperature is obtained which agrees with our simulation results. This temperature scaling indicates that it may be possible to tune the temperature of the hot electrons generated by the super-intense ignition pulse for optimal core heating by manipulating the properties of the material inside the cone target.

[1]Work supported by DOE/NNSA grant DE-FC52-06NA27616 and US Department of Energy under Coopera-tive Agreement DE-FC02-04ER54789. Contributors: B. Chrisman, A. Kemp, and T. Cowan.

Wednesday, November 14, 2007 3:00PM - 5:00PM –
Session QI2 Intense Beams and Accelerators Rosen Centre Hotel Salon 3/4

3:00PM QI2.00001 High Intensity e-beam Diode Development for Flash X-ray Radiography[1] , BRYAN OLIVER, Sandia National Laboratories

— A variety of electron beam diodes are being used and developed for the purpose of creating high-brightness, flash x-ray radiography sources. In these diodes, high energy (multi MeV), high current (multi kA), small spot (multi mm) electron beams are generated and stopped in high atomic number anode-targets (typically Ta or W). Beam stopping in the target creates copious amounts of bremsstrahlung radiation. In addition, beam heating of the target liberates material, either in the form of low density ($\sim 10^{12}$-10^{14} cm^{-3}) ion emission or higher density ($> 10^{15}$ cm^{-3}) plasma. In all cases, beam/target collective effects dominate the diode and beam characteristics, affecting the radiation properties (dose and spot-size). Recent experiments at Sandia National Laboratories have demonstrated diodes capable of producing > 350 rad@m with 1.7mm FWHM x-ray source distributions. A review of our present theoretical understanding of the diode (s) operation and our experimental and simulation methods to investigate them will be presented. Emphasis will be given to e- beam sources used on state-of-the-art Inductive Voltage Adder (IVA) pulsed-power accelerators. In particular, the physics of magnetically pinched diodes (e.g. the rod-pinch [1,2]), gas-cell focusing diodes [3] and the magnetically immersed [4] diode will be discussed. Various proposed methods to optimize the x-ray intensity and the direction of future diode research will be discussed.

[1] G. Cooperstein, et al., Phys. Plasmas **8**, 4618 (2001).
[2] B.V. Oliver et al., Phys. Plasmas **11**, 3976 (2004)
[3] B.V. Oliver, et al., IEEE Trans. on Plasma Science **33**, 704 (2005).
[4] M.G. Mazarakis, et al., Appl. Phys. Lett. **70**, 832 (1997)

[1]In collaboration with the Atomic Weapons Establishment, U.K., the Naval Research Lab, Los Alamos National Laboratories and NSTec.

3:30PM QI2.00002 Time Resolved Imaging of Longitudinal Modulations in Intense Beams[1] , KAI TIAN, Institute for Research in Electronics and Applied Physics, University of Maryland, College Park, MD 20742

— The longitudinal evolution of high intensity beams is not well understood despite its importance to the success of such applications as free electron lasers and light sources, heavy ion inertial fusion, and high energy colliders. For example any amplification of current modulations in an FEL photoinjector can lead to unwanted coherent synchrotron radiation further downstream in compression chicanes or bends. A significant factor usually neglected is the coupling to the transverse dynamics which can strongly affect the longitudinal evolution. Previous experiments at the University of Maryland have revealed much about the longitudinal physics of space-charge dominated beams by monitoring the evolution of longitudinal perturbations. For the first time, experimental results are presented here which reveal the effect of longitudinal perturbations on the transverse beam distribution, with the aid of several new diagnostics that capture detailed time-resolved density images. A longitudinal modulation of the particle density is deliberately generated at the source, and its evolution is tracked downstream using a number of diagnostics such as current monitors, high-resolution energy analyzers, as well as the transverse imaging devices. The latter consist of a high-resolution 16-bit gated camera coupled with very fast emitters such as prompt optical transition radiation (OTR) from an alumina screen, or fast Phosphor screens with 3-ns time resolution. Simulations using the particle-in-cell code WARP are applied to cross-check the experimental results. These experiments and especially the comparisons to simulation represent significant progress towards understanding the longitudinal physics of intense beams.

[1] Work supported by the U.S. Department of Energy, the Office of Naval Research and the Joint Technology Office

4:00PM QI2.00003 Reduced-Order Simulation of Large Accelerator Structures[1] , SIMON COOKE, Naval Research Laboratory — Simulating electromagnetic waves inside finite periodic or almost periodic three-dimensional structures is important to research in linear particle acceleration, high power microwave generation, and photonic bandgap structures. While eigenmodes of periodic structures can be determined from analysis of a single unit cell, based on Floquet theory, the general case of aperiodic structures, with defects or non-uniform properties, typically requires 3D electromagnetic simulation of the entire structure. When the structure is large and high accuracy is necessary this can require high-performance computing techniques to obtain even a few eigenmodes [1]. To confront this problem, we describe an efficient, field-based algorithm that can accurately determine the complete eigenmode spectrum for extended aperiodic structures, up to some chosen frequency limit. The new method combines domain decomposition with a non-traditional, dual eigenmode representation of the fields local to each cell of the structure. Two related boundary value eigenproblems are solved numerically in each cell, with (a) electrically shielded, and (b) magnetically shielded interfaces, to determine a combined set of basis fields. By using the dual solutions in our field representation we accurately represent both the electric and magnetic surface currents that mediate coupling at the interfaces between adjacent cells. The solution is uniformly convergent, so that typically only a few modes are used in each cell. We present results from 3D simulations that demonstrate the speed and low computational needs of the algorithm.

[1] Z. Li, et al, Nucl. Instrum. Methods Phys. Res., Sect. A 558 (2006), 168-174.

[1]This work is supported by the Office of Naval Research.

4:30PM QI2.00004 A brightness transformer using a beam driven plasma wake field accelerator , ERDEM OZ[1], University of Southern California — High brightness electron beams are essential for many physics applications, colliders and light sources such as X-ray FEL at SLAC Linear Coherent Light Source (LCLS), Berkeley Advanced Light Source (ALS), and Argonne Advanced Photon Source (APS). Currently operational state of the art photo injectors can produce electron beams with brightness as high as 10^{13} A/(mrad)^2. Here we introduce a new scheme for producing an electron beam with ultra-high brightness. 2D fully parallel PIC simulations of a plasma wakefield experiment driven by an ultrarelativistic drive beam are performed. The simulations show that ultra-high gradient longitudinal fields (>40 GV/m) trap plasma electrons; trapped electrons form a bunch which has a brightness value ($> 10^{15}$A/mrad^2) two orders of magnitude greater than that of the drive beam. The simulations results are supported by the experimental data taken at the Stanford Linear Accelerator Center. Using the simulations we also show how the brightness can be optimized by changing the drive beam parameters.

[1]Co-authors e167 Collabaration.

Thursday, November 15, 2007 8:00AM - 9:00AM – Session SR1 Review: Maxwell Prize Address Rosen Centre Hotel Junior Ballroom

8:00AM SR1.00001 The Development of ICF and the countdown to ignition experiments on the NIF , JOHN LINDL, Lawrence Livermore National Laboratory — Over three decades of development in Inertial Confinement Fusion are reaching culmination with completion of the National Ignition Facility, expected early in calendar 2009. The first beams will be delivered to target chamber center in October 2007 and Early Opportunity Shot (EOS) experimental campaigns with an increasing number of beams will commence shortly thereafter. The purpose of these campaigns is to begin integrating all of the equipment needed, and demonstrating the performance required, for ignition experiments. This includes the NIF laser, the target cryogenic system, the NIF targets and the NIF target diagnostics. A major campaign with 96 beams (half of NIF's beams) in a symmetric configuration is planned for summer 2008. The purpose of the 96 beam EOS campaign is to pick the hohlraum temperature, laser beam phase plates, and laser energy for the first ignition experiments. This talk will review some of the key physics and technology milestones in ICF over the past three decades, discuss the NIF ignition campaign strategy, and address possible future directions in ICF research. This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Thursday, November 15, 2007 9:30AM - 12:30PM – Session TI1 Ignition Target Design and Laser-Plasma Instabilities Rosen Centre Hotel Junior Ballroom

9:30AM TI1.00001 Robustness studies of NIF ignition targets in two dimensions[1] , DANIEL CLARK, Lawrence Livermore National Laboratory — Inertial confinement fusion capsules are critically dependent on the integrity of their hot spots to ignite. At the time of ignition, only a certain fractional perturbation of the nominally spherical hot spot boundary can be tolerated and the capsule still achieve ignition. The degree to which the expected hot spot perturbation in any given capsule design is less than this maximum tolerable perturbation is a measure of the ignition margin or robustness of that design. Moreover, since there will inevitably be uncertainties in the initial character and implosion dynamics of any given capsule, all of which can contribute to the eventual hot spot perturbation, quantifying the robustness of that capsule against a range of parameter variations is an important consideration in the capsule design. Here, the robustness of the 300 eV indirect drive target design for the National Ignition Facility (NIF) [J. D. Lindl, *et. al.*, Phys. Plasmas **11**, 339 (2004)] is studied in the parameter space of inner ice roughness, implosion velocity, and capsule scale. A suite of two thousand two-dimensional simulations, run with the radiation hydrodynamics code Lasnex, is used as the data base for the study. For each scale, an ignition region in the two remaining variables is identified and the "ignition cliff" is mapped. In accordance with the theoretical arguments of W. K. Levedahl and J. D. Lindl [Nucl. Fusion **37**, 165 (1997)] and R. Kishony and D. Shvarts [Phys. Plasmas **8**, 4925 (2001)], the location of this cliff is fitted to a power law of the capsule implosion velocity and scale. It is found that the cliff can be quite well represented in this power law form, and, using this scaling law, an assessment of the overall (one- and two-dimensional) ignition margin of the design can be made. The effect on the ignition margin of an increase or decrease in the density of the target fill gas is also assessed.

[1]This work was performed under the auspices of the U.S Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

10:00AM TI1.00002 Multi-Variable Sensitivity Studies of NIF Ignition Targets[1] , JAY SALMONSON, Lawrence Livermore National Laboratory

— Performance of indirect drive ignition targets planned for the National Ignition Facility has been studied with multi-variable sensitivity studies. Large numbers of simulations are run, in each of which a number of parameters are set from statistical ensembles intended to represent expected variations in the variables describing the target. Parameters varied include target dimensions, compositions, densities, laser pulse variations, variations in the hohlraum parameters as they determine pulse shaping and symmetry variations, surface roughness, intrinsic hohlraum asymmetry, beam-to-beam power imbalance, and pointing errors. Statistical samples are very large (10,000) for variations of the 1D spherical implosion, and large enough for meaningful statistics (a few hundred runs) for the 2D variations. The overall performance trends can be quite well predicted from a model that uses second order Taylor series to calculate the implosion velocity and DT fuel entropy, as functions of the target variables. The statistical variations allow us to address quantitatively questions such as "What is the distribution function describing the probability of ignition, given expected shot-to-shot variations in the parameters describing the experiment?"

[1]This work performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

10:30AM TI1.00003 Ignition Capsule Design with a High-Density Carbon (HDC) Ablator for the National Ignition Facility (NIF)[1] , DARWIN HO, Lawrence Livermore National Laboratory

— An ignition capsule with a nano-crystalline, high density, carbon ablator is emerging as a promising alternative target for NIF. There are four main advantages in using the HDC ablator. First, for a given outer radius, the HDC ablator absorbs more hohlraum-driven x-ray energy than for a beryllium ablator. Second, the HDC ablator will have smaller and more uniform crystalline grains than beryllium, enabling more isotropic shock propagation. Third, the higher density reduces the coupling of the DT ice surface and the ablator/ice interface from the unstable ablation front, thereby reducing the growth of the surface perturbations seeded by ice roughness and inner-shell roughness. Fourth, material strength of the HDC can reduce instability growth at early times. Possible - though surmountable - challenges include: (1) The ice surface might in fact be rougher because of differences in the beta-layering in HDC vs Beryllium. (2) The need for smoother outer ablator surfaces because of slightly lower ablation rates, and larger mass perturbations for a given surface roughness. (3) Ensuring that the HDC does not spend time in a partially melted state in which density or velocity variations could seed Rayleigh-Taylor instabilities, the 2nd shock should completely melt the HDC ablator. LASNEX design simulations show good 1-D performance and overall favorable 2-D stability behavior. In particular, the ablator is completely melted upon the arrival of the 2nd shock, the capsule can tolerate about twice as rough a DT ice surface as with Beryllium, and instability growth is reduced by material-strength in the HDC ablator.

[1]This work was performed under the auspices of the U.S. DOE by the University of California, LLNL under contract No. W-7405-Eng-48.

11:00AM TI1.00004 Analyses of laser-plasma interactions in National Ignition Facility (NIF) ignition targets[1] , D.E. HINKEL, University of California Lawrence Livermore National Laboratory

— Achieving indirect drive ignition on NIF requires hohlraum targets (high-Z cylinders) that provide good symmetry with acceptable energetics. In these first ignition targets we have elected to optimize ignition hohlraums in a linear regime for laser-plasma interactions (LPI), i.e. where laser light resonantly scatters off linear ion acoustic or electron plasma waves. In this regime we can quantitatively analyze how backscatter affects propagation and deposition of the laser beams within the target. We use pF3D[2] to calculate the reflectivity and deposition profile along a laser beam path in our ignition designs. pF3D is a wave optics beam propagation code designed to model stimulated scatter in the linear regime. It has recently been shown to successfully model NIF-relevant LPI experiments shot on the Omega laser. Unprecedented simulations of whole and near-whole laser beam propagation in ignition targets have been performed. These simulations propagate a realistic laser beam from where it enters the target to the target wall, and include both axial and transverse gradients in the plasma profiles. Such calculations are massively parallel, requiring more than 8000 cpus. We present simulations of 300 eV, 285 eV and 270 eV ignition designs driven at 1 to 1.3 MJ of laser energy at wavelength 351 nm. We discuss the total reflectivity, importance of ensuring good speckle statistics and show the role of re-absorption of the backscattered light on the laser energy deposition rate.

[1]Work performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

[2]R. L. Berger, C. H. Still, E. A. Williams, and A. B. Langdon, *Phys. Plasmas* **5**, 4337 (1998).

11:30AM TI1.00005 Predictive modeling of Omega Laser Plasma Interaction Experiment[1] , LAURENT DIVOL, LLNL

— We have developed a new target platform to study Laser Plasma Interaction in ignition-relevant condition at the Omega laser facility (LLE/Rochester)[1]. By shooting an interaction beam along the axis of a gas-filled hohlraum heated by 15 kJ of heater beam energy, we were able to create a millimeter-scale underdense uniform plasma at electron temperatures above 3 keV. Extensive Thomson scattering measurements allowed to benchmark our hydrodynamic simulations performed with HYDRA [1]. As a result of this effort, we can use with much confidence these simulations as input parameters for our LPI simulation code pF3d [2]. The variety of LPI measurements performed (Stimulated Brillouin and Raman backscattering both in the lens (FABS) and outside (NBI), transmitted light image and energy) allows for a constraining test of our LPI predictive capabilities. We will show that by using accurate hydrodynamic profiles and full three dimensional simulations (see Fig. 1) including a realistic modeling of the laser intensity pattern generated by various smoothing options, linear LPI theory reproduces a variety of measured quantities, including SBS thresholds and absolute reflectivity values, beam spray and the absence of measurable SRS. We will also discuss the effect of beam smoothing techniques (Polarization smoothing, spectral dispersion) on SBS in these targets and compare to experimental data. This good agreement was made possible by the recent increase in computing power routinely available for such simulations, coupled to a detailed description of both plasma and laser parameters.

[1] Phys. Plasmas **14**, 056304 (2007); Phys. Plasmas **14**, 055705 (2007)
[2] Phys. Plasmas 5, 4337 (1998)

[1]This work is partially funded by LDRD 06-ERD-056 and was performed under the auspices of the US Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48. UCRL-MI-230124.

12:00PM TI1.00006 Suppression of Stimulated Brillouin Scattering in multiple-ion species inertial confinement fusion Hohlraum Plasmas.[1] , PAUL NEUMAYER, LLNL — Understanding and control of laser coupling into high-electron temperature hohlraums is important for the success of the indirect-drive approach to inertial confinement fusion (ICF). Parametric instabilities such as stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) can backscatter the incident laser light reducing the total drive energy and affecting radiation symmetry. Consequently, recent hohlraum designs for indirect-drive ignition on the National Ignition Facility investigate wall liner material options so that the linear gain for parametric instabilities will be below threshold for the onset SBS. Increasing the Landau damping of acoustic waves by employing multiple-ion species plasmas offers the perspective of controlling SBS. Although the effect of two-ion species plasmas on Landau damping has been directly observed with Thomson scattering, early experiments on SBS in these plasmas have suffered from competing non-linear effects or laser beam filamentation. In this study, a reduction of SBS in multiple-ion species hohlraum plasmas to below the percent level has been demonstrated. By adding a low-mass ion species (Hydrogen) to a CO2 hohlraum gas fill, the SBS reflectivity was reduced by 3 orders of magnitude. The reduction in the total backscattered energy resulted in an increase of the hohlraum radiation temperature indicating improved coupling of the heater beams. These observations may be scaled to the plasma conditions within ignition scale hohlraums and support employing multiple-ion species plasmas in target designs for the first attempt at ignition on the National Ignition Facility.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Thursday, November 15, 2007 9:30AM - 12:30PM –
Session TI2 Plasma Technology, Nozzles, and the First Wall Rosen Centre Hotel Salon 3/4

9:30AM TI2.00001 Industrial Plasma Antennas[1] , IGOR ALEXEFF, University of Tennessee — This presentation summarizes an extensive program on plasma antennas. Plasma antennas are just as effective as metal antennas. In addition, they can transmit, receive and reflect lower frequency signals while being transparent to higher frequency signals. When de-energized, they electrically disappear. Plasma noise does not appear to be a problem. New technology that has been developed include a method of operating at high plasma density at minimal power consumption, a novel technique of noise reduction, and a method of opening a plasma window in a plasma microwave barrier on a time scale of microseconds rather than the usual time scale of milliseconds due to plasma decay. We are at present testing an intelligent plasma antenna in which a plasma "window" in a circular plasma barrier surrounding an antenna rotates azimuthally, seeking a radio transmitter. When located, a computer locks onto the transmitter. When the transmitter is de-energized, the plasma window recommences scanning. Commercial interest is strong, with invited papers being presented for 4 years in succession at the SMi Stealth Conference in London, UK, an operating model on permanent exhibition at the Booze-Allen headquarters in Alexandria, VA, and strong interest from Lockheed-Martin. In collaboration with Ted Anderson, Haleakala R&D Corp.; Esmaeil Farshi, Fred Dyer, Jeffrey Peck, Eric Pradeep, Nanditha Pulasani, and Naresh Karnam, University of Tennessee.

[1]Work supported by the US Air Force and The U S Army under Phase 2 SBIR Contracts FA9453-06-C-0068 and W15QKN-06-C-0081 respectively.

10:00AM TI2.00002 Measurements of electric field strengths in ionization fronts during breakdown[1] , G.M.W. KROESEN, Eindhoven University of Technology — The electrical field strength during the initial phase of a low pressure, pulsed discharge in Xenon has been measured as a function of spatial position and time using fluorescence-dip Stark spectroscopy. For the first time, the role of the electrical field as the driving force of electrical breakdown has been studied experimentally in detail. A moving ionization front, measured with sub-microsecond resolution, has been detected. In this ionization front, the electrical field is roughly a factor 2 larger than the average in the discharge gap.

[1]In collaboration with E. Wagenaars and M. Bowden, Eindhoven University of Technology.

10:30AM TI2.00003 Plasma Shield for In-Air and Under-Water Beam Processes[1] , ADY HERSHCOVITCH, Brookhaven National Laboratory — As the name suggests, the Plasma Shield is designed to chemically and thermally shield a target object by engulfing an area subjected to beam treatment with inert plasma. The shield consists of a vortex-stabilized arc that is employed to shield beams and workpiece area of interaction from atmospheric or liquid environment. A vortex-stabilized arc is established between a beam generating device (laser, ion or electron gun) and the target object. The arc, which is composed of a pure noble gas (chemically inert), engulfs the interaction region and shields it from any surrounding liquids like water or reactive gases. The vortex is composed of a sacrificial gas or liquid that swirls around and stabilizes the arc. In current art, many industrial processes like ion material modification by ion implantation, dry etching, and micro-fabrication, as well as, electron beam processing, like electron beam machining and electron beam melting is performed exclusively in vacuum, since electron guns, ion guns, their extractors and accelerators must be kept at a reasonably high vacuum, and since chemical interactions with atmospheric gases adversely affect numerous processes. Various processes involving electron ion and laser beams can, with the Plasma Shield be performed in practically any environment. For example, electron beam and laser welding can be performed under water, as well as, in situ repair of ship and nuclear reactor components. The plasma shield results in both thermal (since the plasma is hotter than the environment) and chemical shielding. The latter feature brings about in-vacuum process purity out of vacuum, and the thermal shielding aspect results in higher production rates. Recently plasma shielded electron beam welding experiments were performed resulting in the expected high quality in-air electron beam welding. Principle of operation and experimental results are to be discussed.

[1]Work supported under DOE Contract No. DE-AC02-98CH1-886.

11:00AM TI2.00004 Plasma Physics and Radiation Hydrodynamics in Development of EUV Light Sources for Lithography[1] , KATSUNOBU NISHIHARA, Osaka University — Understanding of radiation generation in laser-produced high-Z plasma (LPP) is important for inertial fusion, astrophysics and x-ray source development. Extreme ultraviolet (EUV) light of 13.5 nm wavelength is strongly desired for manufacture of next-generation microprocessors with node size less than 45 nm. A commercial EUV lithography system would require output EUV power of about 400 W into a solid angle of 2π str within a 2% bandwidth (BW). Laser-produced tin (Sn) plasma at electron temperature of 30-70 eV and ion density of 10^{17-20} cm^{-3} is an attractive light source due to its compactness and high conversion efficiency (CE) from laser to EUV light [1]. The critical issues for practical use are high CE and damage caused by target debris. Many 4d-4f transitions of Sn^{8+} to Sn^{13+} ions mainly contribute to strong emission around 13.5 nm. We first discuss the importance of satellite lines, opacity and photo excitation in radiation transport, especially in high density plasmas produced by 1 μm laser. Experiment and simulation indicate that the maximum CE of 3% is limited by these effects for 1μm laser. We show that the use of a long wavelength laser, such as CO_2 laser, results in higher CE of 3-6%, since the spectral efficiency, the ratio of 13.5 nm emission within 2% BW to total radiation, increases with the reduction of the plasma density. We present theoretical and experimental results of the CE dependence on laser intensity, pulse duration and laser wavelength. Radiation hydrodynamic simulations agree fairly well with EUV spectra observed in the experiments. High energy ions up to 10 keV generated in LPP cause damage to a collecting mirror. We show that the maximum energy is essentially determined from the ratio of plasma radius to Debye length. We also show that the use of the long wavelength laser also reduces the ion energy. We discuss mitigation of high energy ions by a magnetic field and the stability of plasma expansion taking finite ion Larmor radius effects into account.
[1] K. Nishihara et al., Conversion Efficiency of LPP Sources, EUV Sources for Lithography (SPIE Press, Edited by V. Bakshi, (2006)).

[1]Work performed under the auspices of a Leading Project promoted by MEXT in Japan.

11:30AM TI2.00005 Magnetic Nozzle and Plasma Detachment Scenario[1] , BORIS BREIZMAN, Institute for Fusion Studies, The University of Texas at Austin — Some plasma propulsion concepts rely on a strong magnetic field to guide the plasma flow through the thruster nozzle. The question then arises of how the magnetically controlled plasma can detach from the spacecraft. This talk presents a magnetohydrodynamic detachment scenario in which the plasma stretches the magnetic field lines to infinity [1]. Such a scenario is of particular interest for high-power thrusters. As plasma flows along the magnetic field lines, the originally sub-Alfvénic flow becomes super-Alfvénic: this transition is similar to what occurs in the solar wind [2]. In order to describe the detachment quantitatively, the ideal MHD equations have been solved analytically for a plasma flow in a slowly diverging nozzle. The solution exhibits a well-behaved transition from sub- to super- Alfvénic flow inside the nozzle and a rarefaction wave at the edge of the outgoing flow. The magnetic field in the detached plume is almost entirely due to the plasma currents. It is shown that efficient detachment is feasible if the nozzle is sufficiently long. In order to extend the detachment model beyond the idealizations of analytical theory, a Lagrangian fluid code has been developed to solve steady-stated MHD equations and to optimize nozzle efficiency by adjusting the magnetic coil configuration. This numerical tool enables broad parameter scan with modest computational requirements (single workstation). The code has been benchmarked against the idealized analytical picture of plasma detachment and then used to investigate more realistic nozzle configurations that are not analytically tractable. Most recently, the code has been used to interpret experimental data from the Detachment Demonstration Experiment (DDEX) [3] facility at NASA Marshall Space Flight Center. In collabotation with: M. Tushentsov, A. Arefiev, R. Bengtson, J.Meyers (University of Texas at Austin), D. Chavers, C. Dobson, J. Jones (Marshall Space Flight Center), B.Schuettpelz, (University of Alabama in Huntsville), C. Deline (University of Michigan).
[1] A. Arefiev and B. Breizman,Phys. Plasmas **12**, 043504 (2005).
[2] E. N. Parker, Astrophys. J.**128**, 664 (1958).
[3] D. Chavers et al., "Status of Magnetic Nozzle and Plasma Detachment Experiment," CP813, Space Technology and Applications International Forum, pp. 465-473, AIP 2006.

[1]Work supported by US DOE , NASA, and Ad Astra Rocket Company.

12:00PM TI2.00006 Lithium Surface Coatings and Improved Plasma Performance in NSTX[1] , H.W. KUGEL, Princeton Plasma Physics Laboratory, Princeton University, Princeton, NJ 08543 — NSTX research on lithium-coated plasma facing components is the latest step in a decade-long, multi-institutional research program to develop lithium as a plasma-facing system that can withstand the high heat and neutron fluxes in a DT reactor. The NSTX research is also aimed towards sustaining the current non- inductively in H-mode plasmas which requires control of both wall recycling and impurity influxes. Employing several techniques to coat the plasma facing components (PFCs) with lithium, NSTX experiments have shown, for the first time, significant benefits in high-power divertor plasmas. Lithium pellet injection (LPI) uses the plasma itself to distribute lithium on the divertor or limiter surfaces. The multi-barrel LPI on NSTX can introduce either lithium pellets with masses 1 - 5 mg or powder during a discharge. This significantly lowered recycling and reduced the density in a subsequent NBI-heated, divertor plasma. Lithium coatings have also been applied with a LIThium EvaporatoR (LITER) that was installed on an upper vacuum vessel port to direct a collimated stream of lithium vapor toward the graphite tiles of the lower center stack and divertor. The lithium was evaporated either before tokamak discharges, or continuously between and during them. By evaporating lithium into the helium glow discharge that typically precedes each tokamak discharge, a coating of the entire PFC area was achieved. Lithium depositions from a few mg to 1 g have been applied between discharges. Among the effects observed in subsequent neutral-beam heated plasmas were decreases in oxygen impurities, plasma density, and the inductive flux consumption, and increases in electron temperature, ion temperature, energy confinement and DD neutron rate. In addition, a reduction in the ELM frequency, including their complete suppression, was achieved in H-mode plasmas. Additional observations, such as, the duration of the lithium coatings, increases in core metal impurity radiation, and diagnostic window depositions will also be discussed.

[1]Work supported by US DOE Contract DE-AC02-76CH03073.

Thursday, November 15, 2007 9:30AM - 11:54AM –
Session TO3 Magnetic Confinement Theory Rosen Centre Hotel Salon 9/10

9:30AM TO3.00001 Decoupling of ion and electron heat transport via scale separation , FRANK JENKO, Max-Planck-Institut, TOBIAS GOERLER, TERRY RHODES, STAN KAYE — Traditionally, turbulent transport is thought to be carried mainly by long-wavelength modes with $k_\perp \rho_i \sim 0.2$. While this seems to be generally true for the ion heat channel, there is experimental evidence that the electron heat fluxes behave differently – both in transport barriers and beyond. Here, we will examine the spectral properties of heat transport in nonlinear gyrokinetic simulations with the Gene code, focussing on contributions from shorter wavelengths than the ones mentioned above. Some simulations treat both ion and electron space-time scales fully self-consistently and are therefore very challenging from a computational point of view, requiring of the order of 100,000 CPU-hours or more. In pure ITG and TEM turbulence, the heat fluxes exhibit clear peaks around $k_\perp \rho_i \sim 0.2$, and fall off quickly for higher wavenumbers. However, in cases for which TE/ITG modes and ETG modes coexist, the spectral properties may change completely. Now, a wide range of wavenumbers, from ion scales all the way to electron scales, can contribute to the overall electron heat transport. This implies that the latter is dominated by high-wavenumber TEMs and ETG modes, while the direct contribution from ITG modes is relatively small. Applications to recent experiments at both DIII-D and NSTX will be discussed. Here, the concept of scale separation turns out to be crucial for the interpretation of experimental data.

9:42AM TO3.00002 Gyrokinetic Turbulence Simulations for Stellarators , F. MERZ, P. XANTHOPOULOS, T. GORLER, F. JENKO, D. MIKKELSEN, IPP Greifswald — While there is an abundance of publications on plasma microturbulence in tokamaks, not much is presently known about its character in nonaxisymmetric devices. The present work constitutes the first attempt to investigate turbulent transport in modern stellarators, using the gyrokinetic turbulence code GENE and realistic magnetic equilibria. First, linear and nonlinear gyrokinetic simulations of ion-temperature-gradient (ITG) and trapped electron modes are presented for the optimized stellarator Wendelstein 7-X which is currently under construction at Greifswald, Germany. The newly developed code TRACER – based on field line tracing – is employed to extract the required geometric information from the MHD equilibria [Phys. Plasmas **13**, 092301 (2006)]. Extensive linear studies reveal substantial differences with respect to axisymmetric geometry [Phys. Plasmas **14**, 042501 (2007)]. Nonlinear ITG simulations are also presented [Phys. Rev. Lett., in print]. Several fundamental features are discussed, including the role of zonal flows for turbulence saturation, the resulting flux-gradient relationship and the co-existence of ITG modes with trapped ion modes in the saturated state. Similar studies will be presented for the stellarator experiment NCSX at PPPL with the aim to comprehend the effects of quasi-axisymmetric geometry on the properties - both linear and nonlinear - of various microinstabilities.

9:54AM TO3.00003 The zonal flow back-reaction on ion-temperature-gradient mode turbulence , JOHAN ANDERSON, EUN-JIN KIM, Sheffield University, JIQUAN LI, YASUAKI KISHIMOTO, Kyoto University — Anomalous transport remains one of the main concerns in magnetically confined plasmas. The anomalous transport in the core is commonly attributed to Ion-Temperature-Gradient (ITG) mode turbulence. There is strong evidence indicating zonal flow suppression of the Ion-Temperature-Gradient (ITG) mode turbulence, specifically close to the linear $\eta_i = L_n/L_{Ti}$ threshold. A critical concept is the transport regulation and transport barrier formation by zonal flows. The present study reports on the effects of zonal flow suppression of the ITG turbulence, suggesting an increase in the effective linear ITG threshold. This is also known as the Dimit's shift. While, the zonal flows are generated from ITG background turbulence by the coherent mode coupling, moreover the zonal flow back-reacts on the ITG mode turbulence resulting in a modified linear ITG mode threshold. It is shown that the short wave length zonal flow suppression of drift wave turbulence is significant, particularly close to the threshold (η_{ith}).

10:06AM TO3.00004 Role of magnetic shear in flow shear suppression , EUN-JIN KIM, University of Sheffield — Flow shear and magnetic shear are thought to be crucial in controlling anomalous transport in laboratory plasmas. In particular, turbulence quenching due to flow shear is believed to be indispensable for the formation of transport barrier and thus plasma confinement. Here, we investigate how magnetic shear interacts with flow shear, affecting turbulence regulation by flow shear in 3D RMHD turbulence [1]. Specifically, we show analytically that near the resonance surface, transport quenching by flow shear is weakened by magnetic shear as the latter interferes with shearing process. Anomalous particle transport thus becomes more efficient in the regime with stronger magnetic shear for a given flow shear while self-regulation of zonal flows becomes less effective. The results suggest that weak magnetic shear could be favorable for the formation of transport barrier.

[1] E. Kim, Phys. Plasmas, in press (2007)

10:18AM TO3.00005 Trajectory trapping and structure generation in turbulent magnetized plasmas , MADALINA OLIMPIA VLAD, FLORIN SPINEANU, National Institute of Laser, Plasma and Radiation Physics — The ExB drift determines a trapping effect or eddy motion in turbulence with slow time variation. We have shown using a semi-analytical approach that this nonlinear process generates non-standard statistical behavior of the trajectories: memory effects and non-Gaussian probability. The trapped trajectories have quasi-coherent behavior and they form structures similar to fluid vortices. We analyze here the effects of this non-standard statistics of trajectories on the evolution of the drift turbulence in Vlasov description. We consider test modes on turbulent plasma with given statistical characteristics and show that trajectory structures determine the evolution of the drift turbulence toward large scales (inverse cascade). The initial value problem of the drift turbulence is studied. The conclusion is that the main mechanism determining the non-linear evolution of the turbulence toward ordered flow is the trapping and dragging of a part of ions by the potential that moves with the diamagnetic velocity accompanied by the opposite direction average motion of the other ions.

10:30AM TO3.00006 A stepped pressure profile model for internal transport barriers[1] , MATTHEW HOLE, Australian National University, STUART HUDSON, Princeton Plasma Physics Laboratory, ROBERT DEWAR, Australian National University — We develop a multiple interface variational model, comprising multiple Taylor-relaxed plasma regions separated by ideal MHD barriers. The magnetic field in each region is Beltrami, $\nabla \times \mathbf{B} = \mu \mathbf{B}$, and the pressure constant. Between these regions the pressure, field strength, and rotational transform ι may have step changes at the ideal barrier. A principle motivation is the development of a mathematically rigorous ideal MHD model to describe intrinsically 3D equilibria, with nonzero internal pressure, using robust KAM surfaces as the barriers. As each region is locally relaxed however, such a model may also yield reasons for existence of internal transport barriers (ITBs). Focusing on the latter, we build on Hole *et al* Nuc. Fus. 47, pp746-753, 2007, which recently studied the stability of a two-interface periodic-cylinder configuration. In this work, we perform a stability scan over pressure and ι for a two-interface configuration with no jump in ι, and compare the characteristics of stable equilibria to those of ITB's.

[1]The authors would like to acknowledge the support of the Australian Research Council, through grant DP0452728.

10:42AM TO3.00007 Self-consistent Modeling of the Pedestal in Tokamak H-mode Plasmas , A.Y. PANKIN, G. BATEMAN, A.H. KRITZ, Lehigh U., C.S. CHANG, S. KU, G. PARK, NYU, J. CUMMINGS, Caltech, C. SOVINEC, U. Wisconsin, P. SNYDER, General Atomics, L.D. PEARLSTEIN, LLNL, N. PODHORSZKI, UC Davis, S. KLASKY, ORNL — Simulations of H-mode pedestal growth and ELM crashes in DIII-D discharges are carried out using a combination of four computer codes — XGC gyro-kinetic, TEQ equilibrium, ELITE linear ideal MHD stability, and NIMROD extended MHD. The pedestal modeling uses computational tools that are most appropriate for the different physical effects and processes. The approach results from a multi-institutional effort to build a robust suite of codes for self-consistent modeling of the H-mode pedestal in tokamak plasmas. The XGC code is used for modeling of neoclassical effects that lead to the H-mode pedestal formation. The XGC code handles charged particle and neutral collisions using a Monte Carlo approach and a model for the source of neutrals at the wall. The TEQ free-boundary equilibrium code is used to follow the equilibrium changes as the plasma profiles evolve in XGC. The triggering of an ELM crash is indicated by the ELITE code, which computes the linear growth rate of selected modes and takes into account the stabilizing diamagnetic effect. Once an ELM crash is triggered, the NIMROD code is used to follow the nonlinear evolution of the ELM crash. The comparison of the numerical simulations and DIII-D data is discussed.

10:54AM TO3.00008 Linear theory of n=0 geodesic acoustic mode[1] , T. ZHOU, H.V. WONG, H.L. BERK, University of Texas at Austin — The n=0 geodesic acoustic mode (GAM), observed in JET and D- III D is frequently accompanied by fast frequency chirping. A numerical investigation on CASTOR revealed that a global GAM mode arises if the continuum geodesic frequency vs. radius has a local maximum. The global GAM properties are characterized by: a small upward frequency shift from the continuum, radially localized electrostatic components with poloidal numbers m=0,1 and magnetic coupling to a nonlocalized to m=2 component. Here we develop an analytic MHD theory of this n=0 global GAM in a toroidal plasma with r/R and beta small. We choose to start from the MHD quadratic form (with inertial terms). We find the GAM eigenmode is characterized by a radially localized density perturbation and a one order smaller magnetic perturbation that extends throughout the plasma. Its verified that mode existence requires that the continuum GAM profile has a maximum as a function of radius. An asymptotic matching technique shows that the eigenmode frequency shifts from the maximum continuum proportional to the square of the local beta.The asymptotic method agrees precisely with the numerical results.

[1]supported by DOE grant DE-FG02-04ER5474.

11:06AM TO3.00009 The ideal stability of unity beta tokamaks , P.-A. GOURDAIN, S.C. COWLEY, UCLA —

The theoretical stability of unity beta equilibria was left unresolved for many years. Using modern computational tools, unity beta configurations stable to all ideal MHD criteria (Mercier, high-n ideal ballooning, fixed and free boundary modes) have been discovered. They are based on a double equilibrium solution of the Grad-Shafranov equation. The interior solution is highly diamagnetic (reaching unity beta on axis) but usually unstable to free boundary modes. The outer part of the equilibrium is paramagnetic and acts as a perfectly conducting wall surrounding the diamagnetic solution, in effect stabilizing the free boundary modes.

11:18AM TO3.00010 Dust dynamics and diagnostic applications in quasi-neutral plasmas and magnetic fusion , ZHEHUI WANG, CATALIN M. TICOS, JIAHE SI, GIAN LUCA DELZANNO, GIANNI LAPENTA, GLEN WURDEN, Los Alamos National Laboratory —

Little is known about dust dynamics in highly ionized quasi-neutral plasmas with ca. 1.0 e+20 per cubic meter density and ion temperature at a few eV and above, including in magnetic fusion. For example, dust motion in fusion, better known as UFO's, has been observed since 1980's but not explained. Solid understanding of dust dynamics is also important to International Thermonuclear Experimental Reactor (ITER) because of concerns about safety and dust contamination of fusion core. Compared with well studied strongly-coupled dusty plasma regime, new physics may arise in the higher density quasi-neutral plasma regime because of at least four orders of magnitude higher density and two orders of magnitude hotter ion temperature. Our recent laboratory experiments showed that plasma-flow drag force dominates over other forces in a quasi-neutral flowing plasma. In contrast, delicate balance among different forces in dusty plasma has led to many unique phenomena, in particular, the formation of dust crystal. Based on our experiments, we argue that 1) dust crystal will not form in the highly ionized plasmas with flows; 2) the UFO's are moving dust dragged by plasma flows; 3) dust can be used to measure plasma flow. Two diagnostic applications using dust for laboratory quasi-neutral plasmas and magnetic fusion will also be presented.

11:30AM TO3.00011 Dust in Fusion Plasmas: Modeling Approach[1] , R.D. SMIRNOV, A.YU. PIGAROV, S.I. KRASHENINNIKOV, M. ROSENBERG, D.A. MENDIS, UCSD —

The confinement of enormous energy in the plasma of future fusion devices presents numerous challenges associated with unavoidable interactions of the plasma with bounding walls. The interactions both continuous and intermittent lead to destruction of the walls with the release of a significant amount of wall material in the form of atoms, clusters and dust into the plasma. It appears that the dust is not directly affected by the magnetic field and may have a shorter path toward the plasma core, delivering impurities to it. Part of the impurities re-deposits on the plasma facing surfaces as thin films, stimulating further dust production. While in the plasma, the dust particles driven by plasma flows acquire large speeds, this leads to dust spreading over the volume and the surfaces of a fusion device. Taking into account the high reactivity of the dust and its ability to retain tritium, dust also presents important safety issue in the next-step fusion devices. In this work we report on recent progress in numerical simulation efforts with the DUSTT code toward understanding the dust behavior in fusion plasmas. Dust dynamics, transport, statistics, and impact on the plasma are considered.

[1]Work supported by USDoE grant DE-FG02-04ER54852 at UCSD.

11:42AM TO3.00012 Modeling of Dust-Wall Collisional Characteristics in Tokamaks[1] , DAVID BENSON, ROMAN SMIRNOV, UCSD —

Interaction of plasma with plasma facing components in fusion devices leads to dust production, which can enhance impurity inflow toward the core plasma. It is known that the dust particles are accelerated by plasma flows in tokamaks to high speeds ($\sim$1km/s) that under effect of centrifugal acceleration leads to intensive dust-wall collisions. The collisions may lead as to dust fracturing and destruction as well as to avalanche-like mechanism of dust production [1] depending on properties of the dust and the target surfaces. Parameters of the collisions including the coefficient of restitution, the rebound angle distribution, the loss of dust mass as well as the probabilities of dust sticking to the wall and secondary dust production are not well known for fusion related materials and the speed range of interest. In this work the dust-wall collisions are simulated using the LS-DYNA code to explore their effect on the dust transport in tokamaks. Comparison with available experimental data is presented.

[1] S.I. Krasheninnikov et al., IAEA-CN-149/TH/P6-18

[1]Work is partially supported by US DOE grant DE-FG02-04ER54852.

Thursday, November 15, 2007 9:30AM - 12:30PM – Session TO4 JET, EAST, RFX and FRCs Rosen Centre Hotel Salon 1/2

9:30AM TO4.00001 High beta-N experiments at JET[1] , CLIVE CHALLIS, Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon OX14 3DB, UK, JET EFDA CONTRIBUTORS TEAM[2] —

JET has investigated the performance potential and limitations of highly triangular plasmas relevant to fully non-inductive tokamak operation. The q-profile shape has been varied from cases with highly negative core magnetic shear to low shear with q0 close to 1, allowing the effect on confinement and stability to be studied. Operation with beta-N above the no-wall 'limit' has been demonstrated for durations comparable with the resistive time and direct measurements of the no-wall beta have been developed as a tool for systematic performance optimization. Regimes have been developed with ITBs at reduced plasma current and toroidal field (1.2-1.5MA/2.3-2.7T) to obtain high values of beta-N and beta-P with either impurity seeding or quasi-double-null plasma configurations used to mitigate ELMs. The importance of the q-profile shape for performance optimization has been demonstrated in plasmas without ITBs (1.2MA/1.8T) with low values of minimum q (1-2) providing access to the highest beta-N (above 3).

[1]Work partly funded by Euratom and UK EPSRC.

[2]see the Appendix of M L Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006).

9:42AM TO4.00002 Toward the stationary operation at high β_N at JET: experiments and modelling[1] , I. VOITSEKHOVITCH, C.D. CHALLIS, C. GIROUD, UKAEA UK, R.V. BUDNY , D. MCCUNE, PPPL USA, P. BURATTI, ENEA, E. JOFFRIN, CEA, T.C. LUCE, GA USA, M. MURAKAMI, ORNL USA, JET EFDA TEAM —

Recently, a route to stationary MHD stable operation at high β_N has been explored at JET by optimising the current ramp up, preheat start time and the waveform of NBI power in high triangularity plasmas. Transient $\beta_N \approx$3.5 and stationary $\beta_N \approx$3 have been achieved. The results of the analysis of current drive and transport in these discharges can be summarised as: (a) 50-70% of current is driven non-inductively (NI); (b) a half of this current is due to the bootstrap (BS) current; (c) broad BS current profile is produced since the ITB was deliberately avoided; (d) a large contribution to the BS current is due to the ∇Te term; (e) the GLF23 model predicts the temperature profiles within 20% of discrepancy with the data, this model has been benchmarked in ASTRA, ONE-TWO and TRANSP. Based on this analysis the optimisation of high β_N scenario towards fully NI stationary operation by optimising the BS current is investigated in predictive modelling coupling the transport, current diffusion and NBI and including the feedback control of β_N. A projection of this regime to ITER will be discussed.

[1]Funded jointly by the UK EPSRC and EURATOM.

9:54AM TO4.00003 Reversed shear Alfvén Eigenmodes in the frequency range of the triangularity induced gap on JET[1] , G.J. KRAMER, G.Y. FU, R. NAZIKIAN, R.V. BUDNY, N.N. GORELENKOV, PPPL, C.Z. CHENG, Cheng-Kung Univ.,Taiwan, B. ALPER, S.D. PINCHES, F. RIMINI, S.E. SHARAPOV, P. DE VRIES, K-D. ZASTROW, V. ZOITA, Euratom/UKAEA,UK, JET-EFDA COLLABORATION[2] — In reversed magnetic shear plasmas a class of Alfvén eigenmodes (AE) can exist, the Reversed shear Alfvén eigen modes (RSAE). They are often observed in Tokamaks and are located just above the local maximum of the lower TAE continuum gap at the shear reversal point. Similar maxima exist in the higher order Alfvén gaps such as the EAE and NAE gap. In this presentation we will show from ideal MHD simulations and analytical theory that modes similar to the RSAE can exist under certain conditions in those higher order gaps. In burning plasmas modes in the AE gaps can be harmful for the confinement of fusion born alpha particles which can get lost before they thermalize thereby reducing the efficiency of a fusion reactor. We will show experimental evidence for RSAEs in the NAE gap in JET discharges. The JET NAE-RSAEs are identified from state of the art MHD simulations with the NOVA code in which the experimentally observed equilibrium parameters were used.

[1]US DOE contract DE-AC02-76-CH03073

[2]M L Watkins et al., Fusion Energy 2006, Chengdu, IAEA, (2006)

10:06AM TO4.00004 EAST First Plasma – Design, Simulation & Experimental Results[1] , J.A. LEUER, D.A. HUMPHREYS, A.W. HYATT, G.L. JACKSON, R.D. JOHNSON, B.G. PENAFLOR, D.A. PIGLOWSKI, M.L. WALKER, A.S. WELANDER, General Atomics, D. MUELLER, PPPL, B.J. XIAO, Q.P. YUAN, H.Z. WANG, ASIPP, EAST TEAM — First plasma was achieved in EAST, the world's first highly-shaped fully superconducting tokamak, in Sept. 2006 [1]. We describe the design of the first plasma scenario and present results of the first plasma campaign in which this scenario was used successfully. Tools and methods used to optimize the breakdown and initial plasma current ramp follow previous analyses performed for ITER [2]. Testing of the EAST plasma control system (PCS) realtime software against simulations was crucial in designing the scenario. Open loop, resistor-based startup followed by PF current control produced 220 kA plasma current in a circular limiter configuration, with feedback control of plasma current and radial and vertical position. These modeling and design methods are expected to be important to future devices like KSTAR and ITER.
[1] B. Wan, et al., Plasma Sci. & Tech. **9**, 125 (2007).
[2] J.A. Leuer, et al., Proc 15th IEEE Symp. on Fusion Eng. (1993) p. 629.

[1]Supported by the US DOE DE-FC02-04ER54698 and DE-AC02-76CH03073.

10:18AM TO4.00005 Direct Observation of runaway electron beam in EAST , YUEJIANG SHI, BAONIAN WAN, JIA FU, HUIXIAN GAO, YU YANG, JIAHONG LI, XIANG GAO, Institute of Plasma Physics, Chinese Academy of Sciences, EAST TEAM — It is the first time to observe the synchrotron radiation emitted by runaway electrons with a common visible CCD camera in tokamak. Many interesting phenomenon and information about runaway electron has been obtained in EAST, which is the first full superconducting tokamak with non-circular cross-section in the world. Both the energy and pitch angle of runaway electrons have been derived from synchrotron radiation. A test particle dynamics simulation shows the maximum runaway energy in EAST can be noticeably affected by magnetic fluctuation. The synchrotron radiation of runaway electrons was observed in the center region with r<0.25a in most cases. The normal synchrotron radiation pattern is ellipse with an inclination angle to the equator, which is consistent with the numerical calculation of runaway electron synchrotron radiation. In few cases, a stable shell shape of synchrotron radiation can be observed. The MHD activity maybe the reason for the formation of the runaway electron shell. The radial diffusion coefficient of runaway electrons inside the shell is about $0.01 m^2 s^{-1}$. The measurement of synchrotron radiation clear shows that parallel momentum of runaway electrons converts to perpendicular momentum when beam-plasma instability happens.

10:30AM TO4.00006 The ITER ICRF Antenna Design with TOPICA , DANIELE MILANESIO, RICCARDO MAGGIORA, ORSO MENEGHINI, GIUSEPPE VECCHI, Politecnico di Torino — TOPICA (Torino Polytechnic Ion Cyclotron Antenna) code is an innovative tool for the 3D/1D simulation of Ion Cyclotron Radio Frequency (ICRF), i.e. accounting for antennas in a realistic 3D geometry and with an accurate 1D plasma model [1]. The TOPICA code has been deeply parallelized and has been already proved to be a reliable tool for antennas design and performance prediction. A detailed analysis of the 24 straps ITER ICRF antenna geometry has been carried out, underlining the strong dependence and asymmetries of the antenna input parameters due to the ITER plasma response. We optimized the antenna array geometry dimensions to maximize loading, lower mutual couplings and mitigate sheath effects. The calculated antenna input impedance matrices are TOPICA results of a paramount importance for the tuning and matching system design. Electric field distributions have been also calculated and they are used as the main input for the power flux estimation tool. The designed optimized antenna is capable of coupling 20 MW of power to plasma in the 40 – 55 MHz frequency range with a maximum voltage of 45 kV in the feeding coaxial cables.
[1] V. Lancellotti et al., Nuclear Fusion, **46** (2006) S476-S499

10:42AM TO4.00007 Finite Electron Temperature Effects on Interferometric Measurements in Fusion Plasmas[1] , V.V. MIRNOV, W.X. DING, D.L. BROWER, University of Wisconsin - Madison, Center for Magnetic Self Organization in Lab and Astrophysical Plasmas, University of California at Los Angeles — Finite electron temperature effects on interferometry and polarimetry measurments in burning plasma are considered. In the limit when the wave frequency is much higher than the electron cyclotron frequency, the dispersion relation is derived to lowest order in $T_e/m_ec^2 \ll 1$. Previous analysis of the problem included non-relativistic dispersive corrections only [1]. We show that the relativistic effects are equally important and result in a change of the sign of the thermal correction to the Faraday rotation angle. Experimental observation of the "sign" effect could be important verification of fundamental relativistic physics in high-temperature plasma devices. The implication of the thermal corrections for ITER interferometer diagnostics is discussed.
[1] S.E.Segre, V.Zanza, Physics of Plasmas, **9**, 2919 (2002)

[1]Supported by the U.S.DoE and NSF.

10:54AM TO4.00008 Direct Measurement of the Electron Bernstein Wave Absorption and Current Drive at the WEGA Stellarator. , HEINRICH LAQUA, STEFAN MARSEN, MATTHIAS OTTE, YURIY PODOBA, Max-Planck-Institut fuer Plasmaphysik Euratom Association, JOSEF PREINHAELTER, JAKUB URBAN, Institute of Plasma Physics Association Euratom/IPP.CR — At the WEGA, which is a classical five period l=2 stellarator with a major radius of 0.72m and an aspect ratio of 6, electron Bernstein wave (EBW) heating by OXB-mode conversion was established for a frequency of 2.45GHz. Typical electron densities of $10^{18} m^{-3}$, which is 12 times the cut-off density, with an electron temperature of $\leq$ 20eV were achieved for 30s operation with an ECRH power of up to 26kW. The low temperature plasma allows the investigation both, the EBW power deposition and current drive profiles by probes. The first was performed by high frequency (12kHz) power modulation and coherent detection of the generated heat waves with Langmuir probes. The second was measured with a $\dot{B}$-loop. The total EBW current was of up to 45A and the related normalised current drive efficiency ζ was 0.48. The EBW propagation is strongly sensitive on the magnetic configuration. Both, the variation of ∇B along B and the shear can be changed individually, which makes WEGA an unique test bed for EBW propagation. As a result of the shear variation an EBW current reversal was found. The results were modelled by 3D ray-tracing calculations for the different magnetic configurations.

11:06AM TO4.00009 Electron temperature measurements and heat transport improvement in the RFX-mod experiment. , ALBERTO ALFIER, FEDERICA BONOMO, PAOLO FRANZ, LIONELLO MARRELLI, ROBERTO PASQUALOTTO, PAOLO PIOVESAN, GIANLUCA SPIZZO, Consorzio RFX, Euratom-ENEA Association, Corso Stati Uniti 4, 35127 Padova - Italy, SILVIA VALERIA ANNIBALDI, Space and Plasma Physics, Association Euratom-VR, EE, Royal Institute of Technology, SE-10044 Stockholm, Sweden — Electron temperature profiles at about 1keV have been measured in the RFX-mod experiment during the recent high plasma current campaign (I_p >1.2MA, $n_e \sim 4 \cdot 10^{19}$): peaked Te profiles, obtained through the Thomson scattering diagnostic, are characterized by a steep gradient in the core during the quasi-single helicity (QSH) state. The formation of well defined magnetic flux surfaces during QSH states determines a reduction of thermal heat conductivity, whose estimate is essential to quantify this transport improvement. We apply the M1TeV code [1] to various experimental scenarios in order to estimate heat diffusivity, then also calculating electron confinement time: in this study, we consider the effect of the increase of plasma current and also of eventual external current drive.
[1] F.Porcelli *et al.*, Phys. Rev. Lett. 82, 1458 (1999).

11:18AM TO4.00010 Enhanced confinement, magnetic topology and diffusion in RFX-mod for poloidal current drive , DAVID TERRANOVA, ALESSANDRA CANTON, PAOLO INNOCENTE, RITA LORENZINI, PAOLO ZANCA, ALBERTO ALFIER, FEDERICA BONOMO, Consorzio RFX, Euratom-ENEA Association, Corso Stati Uniti, 4 35127 Padova, Italy — The oscillating poloidal currrent drive (OPCD) technique proved to be the best way for inducing enhanced confinement regimes in the RFX- mod reversed field pinch. New OPCD experiments were carried out with plasma currents up to 1.4 MA with the virtual shell system operated in the clean mode control scheme. A significant improvement in plasma performaces has been obtained over a large section of the plasma volume (as shown by the electron temperature profiles) by inducing modifications in the radial profile of magnetic fluctuations. The enhanced regimes are studied also in terms of magnetic topology and diffusion by using a field line tracing code based on the radial profiles of tearing mode eigenfunctions reconstructed in toroidal geometry from external magnetic field measurements. Experiments were carried out also with the injection of pellets synchronized with the poloidal position of the OPCD-induced island. Pellet deposition and three dimensional trajectroy are correlated with the magnetic field structure in these enhanced regimes.

11:30AM TO4.00011 High Current Regimes in RFX-mod , MARCO VALISA, T. BOLZONELLA, P. INNOCENTE, L. MARRELLI, S. MARTINI, S. ORTOLANI, R. PACCAGNELLA, M.E. PUIATTI, M. SPOLAORE, P. ZANCA, Consorzio RFX — RFX-mod has explored for the first time the confinement properties of the RFP configuration at plasma currents up to 1.5 MA. Such an accomplishment has been possible for the successful feedback control of the magnetic boundary, whereby an extensive mesh of individually controlled saddle coils have kept below 1 cm the maximum radial excursion of the last magnetic surface resulting from the overlapping of the many m=0 and m=1 MHD modes. Operation at high current has significantly expanded the database for scaling studies. Increasing current the ohmic input power is to be increased, the toroidal loop voltage does not drop significantly and the plasma wall interaction increases in intensity. On the other hand, in stationary regimes, poloidal beta does not decrease with current and is 15% around n/n_G=0.5. In the high current regimes the probability to obtain Quasi Single Helicity states increases and the plasma volume inside the associated transport barrier increases. Both transient and stationary performance records for RFX have been obtained.

11:42AM TO4.00012 Filamented current density structures measured in the edge region of the RFX-mod experiment , M. SPOLAORE, N. VIANELLO, R. CAVAZZANA, E. MARTINES, G. SERIANNI, E. SPADA, M. ZUIN, V. ANTONI, M. AGOSTINI, P. SCARIN, Consorzio RFX, Associazione Euratom-ENEA sulla Fusione, Corso Stati Uniti 4,35127 Padova, Italy — Coherent structures emerging from turbulence background have been detected in the edge region of the RFX-mod Reversed Field Pinch fusion device and are believed to significantly contribute to the particle transport. In order to gain insight into their presence and features a new and original probe system has been used: the system consists of two sets of electric and magnetic probes toroidally spaced by 88 mm. Each set is equipped with a 2-D array of Langmuir probes and a radial array of 3-axial magnetic coils. Magnetic and electrostatic fluctuations can then be measured simultaneously and on the same location with a high time resolution; statistical methods have been applied in order to detect structure-related bursts in the turbulence. It has been found that in the cross-field plane the bursts in density fluctuations correspond to structures, often referred in literature as 'blobs', and are associated to current density filaments, which are mainly oriented along the magnetic field. Work is in progress to compare the current density bursts, as deduced by the magnetic field circulation, with those due to the diamagnetic current density, related to pressure gradient fluctuations.

11:54AM TO4.00013 Dynamic Formation of FRCs on the PHD Experiment[1] , JOHN SLOUGH, SAMUEL ANDREASON, HIROSHI GOTA, CHRIS PIHL, University of Washington — The goal of the Pulsed High Density (PHD) experiment is to reach break-even conditions through the Magneto-Kinetic (MK) compression of the Field Reversed Configuration (FRC). The distributed nature of the MK process provides for highly efficient coupling of bank energy into FRC thermal energy. The FRC is self-compressed to a hot, high density, burning plasmoid. An expansion phase after the burn allows the direct recovery of electrical energy from the heated FRC through induction. The entire process is similar to a reciprocating Brayton engine with no need for flux sustainment. The initial experimental work on PHD has been focused on generating a FRC that has sufficient lifetime, temperature and flux to reach fusion conditions on compression. To achieve this, the largest FRC experiment to date is being constructed. Dynamic formation is employed to produce the FRC during translation resulting in a very high flux, high velocity plasmoid. This process is also thought to generate large sheared axial flows with significant toroidal flux. Experiments with the device operating at half power have achieved initial target parameters with equilibrium temperatures of 300 eV and 15 mWb of flux. Modifications to achieve full power have been completed with the addition of a drift chamber for detailed equilibrium measurements. Results from the first dynamically formed FRCs will be presented.

[1]Work supported by the DOE Office of Fusion Energy Science

12:06PM TO4.00014 Compression of Dynamically Formed and Merged FRCs[1] , GEORGE VOTROUBEK, JOHN SLOUGH, ARTHUR BLAIR, CHRIS PIHL, MSNW, LLC, SAMUEL ANDREASON, RICHARD MILROY, THOMAS WEBER, University of Washington — In order to explore the high energy density approach to fusion, experimental studies of field reversed configuration (FRC) plasma dynamic formation/ acceleration, collisional merging, and compression to high density have been performed in the Inductive Plasma Accelerator (IPA) experiment at MSNW in Redmond, WA. Two identical IPA sources eject FRCs at $\sim$ 250 km/s into a central chamber where they collide, merge, and decay with flux lifetimes of $\sim$ 40 μs. The merged FRC is then magnetically compressed via a 125 kJ bank up to a field of $\sim$1.5 T resulting in a high density plasma. The experimental device now in operation will be discussed. Results from the merging experiments will be presented, as well as results from compression studies. These results will be compared to 2D MHD numerical calculations.

[1]Research funded by a SBIR grant from the Department Of Energy.

12:18PM TO4.00015 FRC rotation control using an electric field , EDWARD RUDEN, Air Force Research Laboratory, MICHAEL FRESE, NumerEx — A Field Reversed Configuration (FRC) spontaneously gains angular momentum about its z-axis over time until an instability with azimuthal mode number $n = 2$ develops. This is potentially a limiting factor for particle confinement in FRC's. Ions diffusing beyond the separatrix having a preferred angular momentum is one cause of rotation. The boundary conditions where the open magnetic field lines outside the separatrix exit the vacuum chamber resulting in a viscous torque being applied to the FRC at the separatrix is another. Controlling the axial electric field via equipotential conducting rings at a fused quartz tube's inner surface where the open field lines exit the vacuum to prevent rotation is considered. Torque on the FRC due to otherwise passive boundary conditions there may thereby be avoided, and spin-up due to particle diffusion countered. A steady state analysis of FRC rotation due to the boundary potential distribution of a perfectly conducting extended MHD plasma obeying generalized Ohm's law, in addition to numerical simulations of the process are presented.

Thursday, November 15, 2007 9:30AM - 12:30PM –
Session TO6 Fast Ignition II Rosen Centre Hotel Salon 5/6

9:30AM TO6.00001 OMEGA EP: Status and Use Planning , D.D. MEYERHOFER, J.H. KELLY, S.J. LOUCKS, R.L. MCCRORY, S.F.B. MORSE, C. STOECKL, Laboratory for Laser Energetics, U. of Rochester — The OMEGA EP Laser Facility will be completed in April 2008, adjacent to the 60beam, 30-kJ OMEGA Laser Facility at the University of Rochester. OMEGA EP will consist of four beamlines with NIF-like architecture. Each of the beams will ultimately produce 10-ns, 6.5-kJ-energy ultraviolet pulses directed into the EP target chamber. Two of the beamlines will also operate as high-energy petawatt (HEPW) lasers, with up to 2.6 kJ each in 10-ps IR pulses. The HEPW beams can be injected into either the EP chamber or the existing OMEGA target chamber for integrated experiments. This talk will describe the project's status and progress in developing of the OMEGA EP Use Plan, including the results of the first two OMEGA EP Use Planning Workshops. This plan will describe the expected experiments, including resources required and opportunities for external user access. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

9:42AM TO6.00002 Integrated Simulation of Fast-Ignition ICF , A.A. SOLODOV, K.S. ANDERSON, R. BETTI, V. GOTCHEVA, J. MYATT, J.A. DELETTREZ, S. SKUPSKY, Fusion Science Center, Laboratory for Laser Energetics, U. of Rochester — To develop a thorough understanding of the complex physics of fast ignition, the numerical modeling of integrated fast-ignition experiments using different types of codes is required. Implosions of DT-filled cryogenic shells with a gold cone inserted to provide a plasma-free pass for an igniting pettawatt pulse need to be simulated using hydrodynamic codes. The transport of relativistic electrons from the inner cone surface to the dense fuel core must be simulated using particle and/or hybrid-PIC codes. To perform an integrated fast-ignition simulation, we have coupled the 2-D cylindrically symmetric hydrocode *DRACO* and the hybrid-PIC code *LSP. LSP* is used to simulate the heating of the dense fuel by hot electrons and to generate additional source terms in the temperature equation used in *DRACO. DRACO* is a 2-D hydrocode that includes all of the necessary physics required to simulate the ignition and burn of an imploded capsule. The plasma profiles in *LSP* are periodically updated according to *DRACO* results. In this talk the results of an integrated fast-ignition simulation will be presented using high-density and high-ρR fuel assembly recently suggested for fast ignition. This work was supported by the U.S. Department of Energy under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789.

9:54AM TO6.00003 Direct-Drive Fuel-Assembly Simulations of Fast-Ignition Cone-in-Shell Implosions , K.S. ANDERSON[1], P.W. MCKENTY, R. BETTI[2], Laboratory for Laser Energetics, U. of Rochester, M.M. MARINAK, LLNL — Cone-in-shell experiments are being designed for fast-ignition (FI) experiments on OMEGA EP. The basic cone-in-shell design consists of a high-density (e.g., gold) cone embedded in the capsule, with the cone tip near the center of the capsule to allow the injection of a high-intensity ignitor beam close to the compressed high-density fuel mass. The presence of the gold cone causes a deviation from a spherical implosion, leading to lower fuel densities and areal densities. Two-dimensional (2-D) hydrodynamic simulations of FI cone implosions are required both to explore the parameter space (e.g., capsule design, laser pulse shape, and pointing) and to optimize the FI fuel assembly. Furthermore, such simulations are crucial to quantify the initial conditions for integrated FI simulations including fast-electron transport. Current work on 2-D, FI cone-in-shell simulations is presented. This work was supported by the U.S. Department of Energy under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789.

[1]Also Fusion Science Center, U. of Rochester
[2]Also, Fusion Science Center, U. of Rochester

10:06AM TO6.00004 Hydrodynamic Relations for Direct-Drive, Fast-Ignition Inertial Confinement Fusion Implosions , C.D. ZHOU, R. BETTI, Fusion Science Center for Extreme States of Matter and Fast Ignition and Laboratory for Laser Energetics, U. of Rochester — Relations between stagnation and in-flight phases are derived both analytically and numerically for hydrodynamic variables relevant to direct-drive inertial confinement fusion implosions. Scaling laws are derived for the stagnation values of the shell density and areal density and for the hot-spot pressure, temperature, and areal density. A simple formula is also derived for the thermonuclear energy gain and in-flight aspect ratio. Implosions of cryogenic DT capsules driven by UV laser energies ranging from 25 kJ to 2 MJ are simulated with a one-dimensional hydrodynamics code to generate the implosion database used in the scaling-law derivation. These scaling laws provide guidelines for optimized fuel assembly and laser pulse design for direct-drive, fast-ignition, and conventional inertial confinement fusion. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789.

10:18AM TO6.00005 Control of the Fast Electron Beam Divergence for Fast Ignition Inertial Fusion , P. NORREYS, Rutherford Appelton Laboratory — The fast electron beam divergence in intense laser plasma interactions is a vital ingredient in determining the success of fast ignition inertial fusion- If it is too large, then the short pulse laser energy required to generate the temperatures needed for hot spark formation becomes impractical to implement on ignition scale facilities. In this talk, I will review the recent experiments performed on the Vulcan PW laser facility to investigate this question. The pulse duration was changed from 0.5 ps - 10 ps and a wide range of plasma diagnostics were fielded. An intensity dependence to the beam divergence has been identified for the first time from these measurements. Simulations show this effect is caused by Rayleigh-Taylor-like rippling of the critical density surface. I will present new ideas on how the divergence can he controlled and the fast electron transport collimated. These are supported by analytic theory and validated by hybrid Vlasov-Fokker-Planck and hybrid particle-in-cell modelling..

10:30AM TO6.00006 Kinetic and Fluid Models of the Filamentation Instability of Relativistic Electron Beams for Fast-Ignition Conditions

, R.W. SHORT, J. MYATT, Laboratory for Laser Energetics, U. of Rochester — Filamentation of relativistic electron beams is a problem of much current interest due to its relevance to the fast-ignition approach to laser-driven fusion, in which such beams must propagate through several hundred microns of dense plasma. Several recent papers have given calculations of temporal growth rates for filamentation based on various fluid and kinetic models.[1,2,3] However, in the fast-ignition scenario it is expected that the instability will amplify as the beam propagates into the plasma, and thus it is of interest to analyze the spatial-growth properties of filamentation. This talk will present results for spatial growth and the related phenomenon of absolute instability of filamentation, and compare fluid and kinetic models of the instability This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

[1] L. Gremillet, G. Bonnaud, and F. Amiranoff, Phys. Plasmas **9**, 941 (2002).
[2] A. Bret and C. Deutsch, Phys. Plasmas **12**, 102702 (2005).
[3] A. Bret, L. Gremillet, and J. C. Bellido, Phys. Plasmas **14**, 032103 (2007).

10:42AM TO6.00007 ABSTRACT WITHDRAWN –

10:54AM TO6.00008 Kinetic and Collisional Effects on the Linear and Non-Linear Evolution of Fast Ignition Relevant Beam Instabilities

, LARISSA A. COTTRILL, B.F. LASINSKI, S.M. LUND, M. TABAK, R.P.J. TOWN, Lawrence Livermore National Laboratory — A crucial issue surrounding the feasibility of fast ignition is the ability to efficiently couple energy from an incident short-pulse laser to a high-density, pre-compressed fuel core. Energy transfer will involve the generation and transport of a relativistic electron beam, which may be subject to a number of instabilities that act to inhibit energy transport. The initial linear and later nonlinear growth phases of these instabilities will evolve differently depending on a number of issues such as the initial beam distribution and collisional effects. Analytical calculations will be presented in the collisionless and collisional limits to demonstrate differences in instability growth in the linear growth phase for advanced distributions such as the relativistic Maxwellian and waterbag, as well as a distribution extracted from explicit PIC simulations of the laser-plasma interaction. Simulations from the LSP code will also be shown to highlight beam transport issues in the nonlinear saturated state. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

11:06AM TO6.00009 Onset of Coherent Electromagnetic Structures In the REB-DT Fuel Interaction for Fast Ignition

, CLAUDE DEUTSCH, LPGP UParis XI, ANTOINE BRET, ETSII Ciudad-Real, MARIE-CHRISTINE FIRPO, LPTP Polytechnique, DEUTSCH COLLABORATION — We stress the combinations of swiftly growing electromagnetic instabilities(EMI) arising in the interaction of relativistic electron beams(REB) with precompressed DT fuels of fast ignition interest for ICF.REB-target system is taken neutral in charge and current with electron distribution functions including beam and target temperatures.We also pay attention to the impact of modes growth rates(GR) of mode-mode coupling and intrabeam scattering. Collisional damping is documented at large wave numbers in terms of skin depth.A quasi-linear approach yields GR below linear ones.One of the most conspicuous output of this combined linear analysis are 3D ridges featuring the largest GR above k- space for an oblique modes propagagtion w.r.t initial beam velocity. Those modes are seen immune to any temperature induced damping. These novel patterns arise from combining Weibel,filamentation and 2-stream instabilities.They persist in the presence of smooth density gradients or strongly applied magnetic fields. In the very early propagation stage,with no current neutralization,and with strong edge density gradients,REB show a typical ringlike and regularly spiked pattern in agreement with recent experimantal and simulation results.

11:18AM TO6.00010 Laser Channeling in Millimeter-Scale Underdense Plasmas of Fast Ignition

, G. LI, R. YAN, C. REN, V.N. GONCHAROV, Laboratory for Laser Energetics, U. of Rochester, T.L. WANG, J. TONGE, W.B. MORI, U of California, LA — Two-dimensional particle-in-cell simulations show that laser channeling in millimeter-scale underdense plasmas is a highly nonlinear and dynamic process involving laser self-focusing and filamentation, channel expansion through ponderomotive blowout and high-Mach-number shock waves, plasma density snow-plowing, laser hosing, and channel bifurcation and merging. The channeling speed is much less than the laser linear group velocity. The simulations find that the channeling time T_c and the total required energy to reach the critical surface, E_c, scale with the laser intensity I as $T_c \sim I^{-0.64}$ and $E_c \sim I^{0.36}$. The scaling shows that low-intensity channeling pulses are preferred to minimize the required pulse energy but with an estimated lower bound on the intensity of $I \approx 4 \times 10^{18}$ W/cm^2 if the channel is to be established within 100 ps. These results will also be compared with those from smaller-scale 3-D simulations. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreements DE-FC52-92SF19460, DE-FC02-04ER54789, and DE-FG02-06ER54879.

11:30AM TO6.00011 Collision of high-velocity impactor with high-density plasma as another pathway towards laser fusion ignition

, HIROSHI AZECHI, TATSUHIRO SAKAIYA, TAKESHI WATARI, HIROSHI SAITO, KAZUTO OHTANI, KAZUO TAKEDA, HIROKAZU HOSODA, HIROYUKI SHIRAGA, MITSUO NAKAI, KEISUKE SHIGEMORI, SHINSUKE FUJIOKA, MASAKATSU MURAKAMI, ATSUSHI SUNAHARA, HIDEO NAGATOMO, KUNIOKI MIMA, ILE, Osaka University, MAX KARASIK, JOHN GARDNER, D.G. COLOMBANT, J.W. BATES, ALEXANDER VELIKOVICH, JOHN SETHIAN, STEVE OBENSCHAIN, Naval Research Laboratory, YAFIM AGLITSKY, SAIC, SHALOM ELIEZER, Soreq NRC, PETER NORREYS, Rutherford Appleton Laboratory — The fast ignition has a potential to have ignition with about one tenth of laser energy required for these programs. However this "conventional" fast ignition approach suffers drawback that physics understanding of hot electron generation and transport is insufficient to make quantitative prediction of the ignition. Here we employ a new approach that totally eliminates this complex problem while keeping the advantage of the compactness of the fast ignition; we accelerated a small portion of the fuel to a super-high velocity to collide with a pre-compressed main fuel. We have observed two orders-of-magnitude increase of neutron yield at the right timing of the impact collision, providing another pathway to compact and reliable fusion energy production

11:42AM TO6.00012 Suprathermal pressure in low mass short-pulse laser irradiated targets[1]

, M. TABAK, Lawrence Livermore National Laboratory — Suprathermal pressure can be a significant parasitic loss in low mass targets illuminated by short-pulse, ultra-high intensity lasers. Recent experiments have used low mass targets as: 1) efficient sources of K$_{alphagg}$ radiation for radiography applications as well as 2) clean measures of laser to suprathermal electron coupling efficiency because electron transport should be less important when the hot electrons fill the target. Recent experiments have shown apparent coupling efficiency at variance with previous experiments and significantly reduced for the thinnest targets. We use the multigroup electron diffusion package in Lasnex to model these experiments. We first model the two-temperature expansion of a collisionless plasma and obtain good agreement with recent calculations of Mora. We then introduce a simple post-processor model for Kalpha$_{\rm gg}$ radiation into collisional, radiative calculations. A significant fraction of the incident energy is directly coupled to the hydrodynamic expansion of the slabs. This accounts for some of the discrepancies with earlier experiments, but still leaves some open questions.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

11:54AM TO6.00013 Recent energy transport experiments on the VULCAN Petawatt laser ,

KATE LANCASTER, STFC Rutherford Appleton Laboratory — VULCAN Petawatt experiments have been performed to investigate aspects of energy transport in solid targets. A range of targets were used to study the transport in insulating (SiO_2) and conducting (Al) materials of similar Z, and low Z materials. Thick SiO_2, Al, and CH targets with copper coated on the rear surface were designed to yield information about energy transport in larger targets of different material properties. Data were obtained from x-ray and optical imaging systems. Unusual patterns in the expansion profiles were observed consistently for the Al case compared with the other target materials. Buried Nickel layers were sandwiched between the thin (2-5μm) target materials (Al, SiO_2,CH) to enable measurement of the Ni Lyman Alpha thermal emission using a spherical crystal imaging system. Data were also obtained from the other x-ray and optical imaging systems. Modeling using hybrid, radiation hydrodynamic, and atomic codes is presented to assist interpretation of the data.

12:06PM TO6.00014 Quenching mode of efficient heating in entrant cone laser interactions.

, H. NAKAMURA, Grad. School of Eng. & ILE, Osaka Univ., B. CHRISMAN, Y. SENTOKU, Nevada Terawatt Facility, Univ. of Nevada, M. BORGHESI, The Queen's Univ. of Belfast, J. FUCHS, Laboratoire pour l'Utilisation des Lasers Intenses, K. KONDO, M. NAKATSUTSUMI, Grad. School of Eng. & ILE, Osaka Univ., M. TAMPO, ILE, Osaka Univ., K.A. TANAKA, T. TANIMOTO, T. YABUUCHI, R. KODAMA, Grad. School of Eng. & ILE, Osaka Univ. — We measured hot electron spectra in ultra intense laser interaction with an entrant cone target attached by fine wire on the tip. Fast heating of the wire with the electron was investigated when the laser pulse was focused into the cone changing the pointing of the laser from the tip center to the side wall. Higher slope components appeared on the high energy tail of the hot electron energy spectra for the illumination on the side wall. In contrast, pointing of the laser on the tip relatively increased the lower energy component of the electrons as compared with that for the illumination on the side wall, resulting in well heating of the wire by more than 1keV. The experiments indicate the importance of the pointing of the laser into cone geometry for fast heating of high density imploded plasmas.

12:18PM TO6.00015 Integrated LSP Modeling of Fast-electron Production and Transport in a Wire Target[1]

, MINGSHENG WEI, JOHN PASLEY, FARHAT BEG, UCSD, RICHARD STEPHENS, General Atomics, DALE WELCH, Voss Scientific — Integrated simulations using the implicit PIC code LSP# have been performed to study the production of relativistic electrons from ultra-intense (I $\sim$ 7 x 10^{19} W/cm^2) sub-picosecond laser solid interactions including a preformed plasma and the transport of such beam in a thin (50 μm in diameter), 100's μm long wire target. Our 3D simulations show that greater than 40% of laser energy is transferred to fast electrons whose energy spectrum can be fitted to a two-temperature Maxwellian distribution. The fast electrons have a typical propagation length of about 100 μm inside the wire target. A very small fraction of the fast electrons is confined in the wire target surface by strong electric and magnetic fields and these electrons have a much longer range. The simulation results agree well with recent Titan wire experiments [1], as well as with other collisional PIC modeling.
[1] F. N. Beg, Invited talk, 9th International Fast Ignition Workshop, Cambridge, MA, Nov. 3-5, 2006; J. Pasley et al., to be submitted to Phys. of Plasmas. #LSP is a software product of ATK Mission Research.

[1]This work is supported by USDOE under DE-FC02-04ER54789, DE-FG02-05ER54834, and DE-FG03-00ER54606. This work is also partially supported by the NCSA under TG-PHY050034T, TG-PHY060020T.

9:30AM - 9:30AM –

Session TP8 Poster Session VII: Reconnection and Non-Neutral II; High Power Microwave and Laser Driven Sources; NSTX Spherical / General Torus; Simulation: HEDP/Plasma Accelerator/Space Rosen Centre Hotel Grand Ballroom, 9:30am - 12:30pm

TP8.00001 RECONNECTION AND NON-NEUTRAL II –

TP8.00002 Hamiltonian Structure of a Collisionless Reconnection Model for High and Low β Plasmas[1]

, P.J. MORRISON, The University of Texas at Austin, Austin, TX, E. TASSI, D. GRASSO, Politecnico di Torino, Torino, Italy, F. WAELBROECK, The University of Texas at Austin, Austin, TX — The noncanonical Hamiltonian formulation of a recently derived four-field model describing collisionless reconnection is presented. The corresponding Lie-Poisson bracket is shown to be a sum of a direct and semi-direct product forms and to possess four infinite independent families of Casimir invariants. Three out of four of these families are directly associated with the existence of Lagrangian invariants of the model. Two of the invariants generalize previously discovered invariants of a two-field model for reconnection in low-β plasmas. The variational principle is given for deriving general equilibrium equations and examples of equilibrium solutions are described explicitly. The normal modes of the system are identified, shown to be second variation (energy) stable, and normal canonical (action angle) coordinates are obtained.

[1]Supported in part by the US Department of Energy Contract No. DE-FG03-96ER-54346.

TP8.00003 Fast magnetic reconnection regime in double tearing modes[1]

, Z.X. WANG, Dalian University of Technology, China, X.G. WANG, Peking University, China, J.Q. DONG, Y.X. LONG, Z.Z. MOU, W.X. QU, Southwestern Institute of Physics — Nonlinear phases of magnetic reconnection in double tearing modes are studied. The first two nonlinear phases of magnetic reconnection lead to the formation of magnetic islands followed by a fast phase to complete the reconnection process with all field lines reconnected and islands vanished. Resistivity dependences for various phases are studied and shown by scaling analysis for the first time. It is shown that after an early non-constant-ψ Sweet-Parker phase with a $\eta^{1/2}$-scale, the long nonlinear phase is in a Rutherford regime with a η-scale following by the fast reconnection phase with a very fast $\eta^{1/5}$-scale. The latter phase is found generated by a process of neighboring magnetic separatrices merging and magnetic islands coupling, with a very fast reconnection rate weakly depended on plasma resistivity. The fast reconnection rate can be understood as a result of the island coupling equivalent to a steadily inward flux boundary driven.

[1]This work is supported by NSFC.

TP8.00004 Effects of a toroidal shear flow on magnetic reconnection[1] , XIAOGANG WANG, Peking University, JIAQI WANG, Dalian University of Technology, China — In laboratory plasmas, a toroidal shear flow V_z can be generated by neutral beam injections (NBI), and in space plasmas, the shear flow V_z perpendicular to the anti-parallel magnetic fields B_y, such as in the magnetosphere plasma, are also observed often. Nevertheless, though magnetic reconnection with a poloidal shear flow V_y, i.e., a flow parallel or anti-parallel to the equilibrium poloidal field, has been studied in space and laboratory plasmas for years, the effect of a toroidal shear flow on magnetic reconnection attracts little attention, since in a two-dimensional geometry the out-of-plane toroidal flow V_z has been thought no effect on the in-plane reconnection process. However, our study on the problem finds that the toroidal shear flow generates a bipolar structure of the perturbed B_z field that excites Alfvén waves downstream away from the reconnection region. Also particularly in collisionless Hall MHD reconnection regime that is often the case in space plasmas, the bipolar structure destroys the quadruple distribution of the B_z field generated by the low frequency whistler modes. The consequence of the effects to tearing modes in tokamaks and collisionless reconnection in space plasmas is also discussed.

[1]This work is supported by NSFC.

TP8.00005 Current-sheet formation in compressible MHD , DAVID ROLLINS, BHIMSEN SHIVAMOGGI, University of Central Florida — Current-sheet formation near a hyperbolic magnetic neutral line in the MHD model is investigated. In this model, the magnetic field lines are swept by the plasma flow toward the X-point. The effects of density variation of the plasma are considered, in particular the case of compressible barotropic plasma.

TP8.00006 Identification of a Two-scale Diffusion Layer During Magnetic Reconnection in a Laboratory Plasma , M. YAMADA, Y. REN, H. JI, S. GERHARDT, B. MCGEEHAN, C. JACOBSON, J. BAUMGAERTEL, R. KULSRUD, S. DORFMAN, Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, PPPL, Princeton U. — Recent results from the Magnetic Reconnection Experiment (MRX)[1] are reported. For the first time in a laboratory plasma, a two-scale diffusion layer in a reconnection region has been identified. Recent 2D numerical simulations predict a thin electron diffusion layer residing inside the broader ion diffusion layer, which has width of approximately the ion skin depth. In our experiments, the electron diffusion layer is also identified inside the ion diffusion region. Demagnetized electrons are found to be accelerated in the outflow, in good agreement with recent numerical simulation data. The measured width of the electron diffusion region scales with the electron skin depth (5-8 c/ω_{pe}), and the electron outflow scales with the electron Alfvén velocity. While the electron outflow appears to slow down by dissipation in the electron diffusion region, the total electron outflow remains independent of its width. The ion outflow channel is shown to be much broader than the electron channel. Our results will be compared with recent space data. The effects of guide field on the layer structure will also be presented. 1. M. Yamada et al, Phys. Plasma v.4, 1936 (1997). Research Supported by DoE, NSF and NASA

TP8.00007 Investigation of the 3-D profile of the reconnection layer with and without a guide field , B. MCGEEHAN, M. YAMADA, H. JI, S. GERHARDT, C. JACOBSON, J. BAUMGAERTEL, S. DORFMAN, Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, PPPL, Princeton U. — In the reconnecting current sheet in the Magnetic Reconnection Experiment (MRX), the electron diffusion region is verified within the ion diffusion region where the ions become demagnetized. This was confirmed through the appearance of the out-of-plane quadrupole field (QF) during the reconnection process. Because of the QF, the reconnection region is no longer 2-D but is stretched in the out-of-plane direction in a bell shape pattern. This three-dimensional picture (while still axisymmetric) is seen with magnetic probes that measure three magnetic field components. Using magnetics data along with mach probe and langmuir probe data will give the profiles of both the ion and electron fluid velocities. Also, the shape of the in-plane magnetic fields are compared with and without the guide field. In null-helicity (without guide field) a narrow and long current sheet is observed, while in co-helicity (with guide field) a broad O-point type reconnection region is observed. A bipolar electric field profile has been measured in MRX. As the current sheet passes the probe array, a dip in the floating potential is evident. This bipolar electric field will also be investigated as a function of guide field. Work supported by DoE, NSF, and NASA

TP8.00008 Study of the Effects of Guide Field on Reconnection in MRX[1] , C. JACOBSON, M. YAMADA, H. JI, S. GERHARDT, B. MCGEEHAN, Center for Magnetic Self-Organization, Princeton Plasma Physics Laboratory — In magnetic reconnection, the presence of the third magnetic field component, or guide field, reduces reconnection rate and tends to form O-shaped diffusion regions [2]. In the Magnetic Reconnection Experiment (MRX), cohelicity merging of two plasma toroids created by a pair of flux cores can produce guide field, however, the magnitude is not easily independently controlled and the field is globally nonuniform. A new toroidal field coil set powered by a 50 kJ capacitor bank capable of producing a uniform guide field with strengths up to 1000 G has been installed on MRX. Other guide field hardware is also described. Initial results of reconnection rate, resistivity, and current sheet tilting and as a function of guide field strength are presented as available. Ion flows are measured with a new Mach probe array, which allows simultaneous measurement of two components of the ion velocity at several points in and near the diffusion region.

[1]This work is supported by DOE, NSF, and NASA.
[2]M. Yamada et al., Phys. Rev. Lett. 78, 3117 (1997).

TP8.00009 Active Perturbations in the Outflow Region of the MRX Current Sheet[1] , J.A. BAUMGAERTEL, S. DORFMAN, B. MCGEEHAN, S. GERHARDT, H. JI, M. YAMADA, Center for Magnetic Self-Organization, Princeton Plasma Physics Laboratory — Electromagnetic fluctuations have been observed in the Magnetic Reconnection Experiment (MRX) in frequencies up to the lower hybrid frequency. These fluctuations may cause anomalous resistivity, which could increase the rate of magnetic reconnection. To characterize these fluctuations, a 1cm radius magnetic dipole antenna is used in the MRX current sheet to launch perturbations at a single frequency. Previous work partially characterized propagation in the direction normal to the reconnection plane. When detection is downstream with respect to the out of plane electron flow, the signal is enhanced above the vacuum value within the current sheet, whereas the signal detected upstream is often reduced below the vacuum value [1]. Current work explores propagation in the outflow direction where a signal that grows in time is often observed. Experiments and analysis are ongoing to investigate the cause and propagation characteristics of this perturbation as well as its effect on the reconnection process.
[1] S. Dorfman et. al., AIP Conf. Proc. 871, 306 (2006)

[1]Supported by DOE, NSF, and NASA.

TP8.00010 Anomalous Resistivity in a Slab Geometry , WILLIAM TANG, SETH DORFMAN, HONG QIN, HANTAO JI, MASAAKI YAMADA, Center for Magnetic Self-Organization, Princeton Plasma Physics Laboratory — A broad spectrum of electromagnetic fluctuations is often observed during fast magnetic reconnection both in nature and in laboratory experiments such as the Magnetic Reconnection Experiment (MRX). While much past work has focused on fluctuations in the lower hybrid range of frequencies[1], the fluctuation amplitudes are higher at lower frequencies below the ion cyclotron frequency. In the present study, we use linear gyrokinetic theory and a simple Krook collision model to examine the conductivity[2] in the presence of a density gradient and constant magnetic field in a parameter regime relevant to the strong guide field case in MRX. A simple Fortran code is used to solve the resulting dispersion relation for the coupled drift and Alfven waves. A robust instability is identified in a broad parameter range. These growing modes are found to have a significant effect on the calculated gyrokinetic conductivity; thus this regime is identified as a promising area for further study with a more complex model. This work was supported by DOE FES Fellowship, DOE, NASA, and NSF.

[1]H. Ji, et al., Phys. Rev. Lett. 92, 115001 (2004)
[2]H. Qin, Princeton PhD Thesis (1998)

TP8.00011 Fully Kinetic Simulations of Driven Magnetic Reconnection with Boundary Conditions Relevant to MRX , S. DORFMAN, Center for Magnetic Self-Organization, Princeton Plasma Physics Laboratory, W. DAUGHTON, V. ROYTERSHTEYN, University of Iowa, H. JI, M. YAMADA, W. TANG, CMSO, PPPL — Many simulations of magnetic reconnection use periodic boundary conditions which limit the physical relevance of the results when comparing with large open systems that occur in nature or with laboratory reconnection experiments. To address this issue, more realistic boundary conditions are employed to model the Magnetic Reconnection Experiment (MRX) using a fully kinetic, two-dimensional code. The simulation is made up of a box with conducting boundary conditions and two current-carrying wires. As the current is ramped down over the time scale of the simulation, a current sheet forms and elongates. Scaling comparisons for the the length and width of the electron layer as well as the reconnection rate are presented. In both the experiment and simulation the thickness of the electron layer scales linearly with the electron skin depth. However, in the experiment, the layer is four to five times thicker [1]. Magnetic islands similar to previous undriven, open-boundary simulations [2] are sometimes observed in the present work but have not been conclusively identified in the experiment. [1] Y. Ren, Princeton PhD Thesis (2007). [2] W. Daughton, et all., Phys. Plasmas. **13**, 072101 (2006). This work was supported by DOE FES Fellowship, DOE, NASA, and NSF.

TP8.00012 New results on the perpendicularly propagating electromagnetic lower hybrid drift instability (LHDI)[1] , YANSONG WANG, RUSSELL KULSRUD, HANTAO JI, Princeton University — Motivated by the observation of the magnetic fluctuations in the current layer of the MRX, we developed an *oblique* LHDI theory [1]. Applying this local theory to the Harris sheet, we found that this local mode is strongly unstable. However, it has such a large group velocity that it propagates out of the unstable region before it grows significantly. In fact, the larger the drift velocity, the more narrow the unstable region, (because the current thickness decreases). Thus, the oblique mode does not seem to be responsible for the observed fluctuations, or any enhanced resistivity. Therefore, we have concentrated on *perpendicular* propagation modes. We have found an unstable mode with a very small group velocity in the gradient direction. this mode has a substantial growth rate and a smaller group velocity so it stays for a longer time in the unstable region. This may be the desired mode. Curiously, it is not made unstable directly by ion Landau damping, but is made unstable by the out-of-phase correction to the perturbed ion density due to the $\delta\mathbf{V}\cdot\nabla n_0$ term.
[1] H. Ji, R. Kulsrud, W. Fox, and M. Yamada, JGR 110, A08212 (2005).

[1]This work is supported by NASA.

TP8.00013 Global Two-Fluid Simulations of Magnetic Reconnection , NICHOLAS MURPHY, CARL SOVINEC, University of Wisconsin and the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas — Two-fluid effects are known to influence the magnetic reconnection process through non-MHD communication between the reconnection layer and surrounding magnetic field topology[1]. To examine the interrelationship between the local reconnection physics and the global magnetic field geometry, we perform two-fluid simulations of the Magnetic Reconnection Experiment (MRX) and the Swarthmore Spheromak Experiment (SSX) using the NIMROD extended MHD code. For MRX, we discuss the effects of toroidicity, the shape of the electron outflow region, and the effect of downstream pressure on the reconnection process. We find that much of the communication between local and global scales is due to the pressure gradients that result from the reconnection outflow. During counter-helicity push reconnection, we observe a radial shift in position of the current sheet and an asymmetric outflow, as seen in experiment[2]. This asymmetric outflow is examined in terms of separate force-density contributions. For SSX, we present simulations of counter-helicity spheromak merging in both prolate and oblate flux conservers, and discuss the impact of geometry as well as two-fluid effects on the reconnection process.
[1]D. Biskamp *et al.*, Phys. Plasmas 4, 1002, (1997).
[2]M. Inomoto *et al.*, Phys. Rev. Lett. 97, 135002 (2006).

TP8.00014 Current Sheet Dynamics in TS-4 Tokamak Reconnection Experiment , YASUSHI ONO, TOMOKI HAYASHI, HEIZO IMANAKA, RYOTA IMAZAWA, University of Tokyo — The current sheet dynamics have been studied in the TS-4 tokamak mergting / reconnection experiment, revealing quasi-steady, transient and intermittent reconnections. Reconnection speed of two tokamak plasmas was varied by acceleration and separation coil currents. When the inflow flux was set larger than the outflow flux, rapid growth of current sheet was followed by its various dynamics, such as sheet deformation, sheet ejection and island structures of the sheet. In the high-q tokamak merging, the sheet resistivity was almost classical due to the sheet thickness larger than ion gyroradius. Large inflow flux and low current-sheet dissipation caused plasma pileup around the sheet, indicating rapid growth of the current sheet. When the flux pileup exceeded a critical limit, the sheet was ejected mechanically from the squeezed X-point area. The reconnection (outflow) speed was slow during the flux pileup and was fast during the ejection, indicating that intermittent reconnection similar to the solar flare increased the averaged reconnection speed. Right after the ejection, the current sheet was often transformed into several current islands, suggesting that the island size comparable with ion gyrodasius increased the sheet resistivity as well as the reconnection speed. These transient effects caused the fast reconnection as well as the high-power reconnection heating in the merging tokamak experiment.

TP8.00015 Mass dependence of impurity ion temperature in a reconnecting laboratory plasma , CHRISTOPHER COTHRAN, Haverford College, MICHAEL BROWN, Swarthmore College — Magnetic reconnection is ubiquitous in magnetized plasmas, occurring in the solar corona, the magnetosphere, as well as in laboratory plasmas. In the corona, ion temperatures are correlated with ion mass (Cranmer, SSR 2002), therefore suggesting that the heating mechanism in the corona, most likely reconnection, is more efficient for more massive ion species. This observation motivated a recent laboratory study at the Swarthmore Spheromak Experiment (SSX). Magnetic reconnection occurs as left– and right– handed spheromaks merge axially within a cylindrical flux-conserving boundary (counter-helicity merging). Doppler broadened and shifted emission lines from impurity ions (He, C, N, O in majority H plasma) are monitored with a fast, high resolution echelle spectrograph (Cothran, RSI 2006) capable of tracking the lineshape at the MHD timescale of the experiment. The well resolved spectral lines intermittently show a double-peaked shape indicative of reconnection outflow at a substantial fraction of the Alfvén speed. Contrary to the results in the corona, however, the He ions appear to be somewhat hotter than the heavier impurity species observed.

TP8.00016 Experiment on two RMF-driven FRCs' magnetic reconnection , TIAN-SEN HUANG, YURI PETROV, XIAOKANG YANG, Prairie View A&M University — Magnetic reconnection experiments in RMF-driven FRC plasma are performed in an 80cm/40cm diameter cylindrical chamber with an additional magnetic coil mounted at the mid-plane. In the experiments, RMF produced by two 500 kHz rf generators drives a plasma current about 2 - 3 kA in the presence of a vertical magnetic field 40 – 60 G. During a 40 ms, 200 kW power discharge, a 10 ms pulse-current above the threshold value 1500 A is applied to the mid-plane coil to sever the plasma current into two rings and form two FRCs. When the current in the mid-plane coil drops to zero, the two FRCs merge into one FRC again. In the experiments, variations in plasma current, magnetic field profile and H-alpha signal were measured. Both the magnetic field evolution and the change of H-alpha signal show the magnetic reconnection process.

TP8.00017 Coalescence of magnetic flux ropes in a 3D reconnection experiment , XUAN SUN, THOMAS INTRATOR, LEONID DORF, GIOVANNI LAPENTA, Los Alamos National Laboratory — The dynamics of magnetic flux ropes are of fundamental importance to the Earth's magnetosphere, solar eruptions, and many other astrophysical phenomena. Understanding the flux rope merging process mainly relies on the spacecraft observation, theory, and numerical simulations while little has been done experimentally. We present experimental results of 3D merging of two flux ropes in the Reconnection Scaling eXperiment (RSX) at Los Alamos National Laboratory. The two flux ropes, or the two current channels embedded in the external magnetic field, are produced by two identical plasma guns. By varying the external magnetic field strength and plasma currents, we study the merging process for strong and moderate guide field. The primary results show the flux ropes undergo a sloshing process in the strong guide field and form a reverse current sheet if one decreases the guide field strength to ∼5 times the anti-parallel field strength. The results confirm that the merging rate is slower at higher guide field.

TP8.00018 Scaling of Reconnection and Stability of Current Sheets in Large Systems[1] , A. BHATTACHARJEE, H. YANG, N. BESSHO, X. QIAN, Center for Integrated Computation and Analysis of Reconnection and Turbulence, and Center for Magnetic Self-Organization, University of New Hampshire — The scaling of collisionless reconnection in two-dimensional large systems has been a subject of considerable interest recently. We have carried out a sequence of simulations using the same initial conditions for large systems using resistive MHD, Hall MHD and PIC techniques. It is shown that the dynamics of thin current sheets is sensitive to the mechanism that breaks field lines (spatially uniform resistivity, electron inertia, and/or electron pressure tensor), and that velocity shear along the thin current sheets plays an important role in controlling their geometry and stability. In the resistive MHD model, the long thin current sheet spanning Y-points become near-explosively unstable to secondary tearing, producing plasmoids. In Hall MHD, the nonlinear dynamics changes qualitatively, as the Y-points contract spontaneously to form X-points thwarting the secondary tearing instabilities seen in the resistive MHD study. A steady state is then realized due to a balance between the spatial gradients of the current density and the velocity shear. Collisionless PIC simulations show a very different dynamics, exhibiting the tendency to form extended thin current sheets and secondary tearing instabilities, as found by W. Daughton and coworkers [Phys. Plasmas **13**, 072101 (2006)].

[1]This research is supported by NSF and DOE.

TP8.00019 Nonlinear evolution of the Resistive Kink Mode and its Nonlinear Stabilization[1] , KAI GERMASCHEWSKI, AMITAVA BHATTACHARJEE, University of New Hampshire — We use the Magnetic Reconnection Code (MRC) to study the nonlinear dynamics of $m = 1$ kink-tearing modes. The MRC a state-of-the art simulation code that implicitly integrates the system of extended MHD equations including a generalized Ohm's law in arbitrary curvilinear coordinates. We employ an inexact Newton method for the solution of the nonlinear implicit equations. The inner linear solve is handled by SuperLU, where the Jacobian matrix is symbolically derived and implemented by a code generator. We demonstrate that nonlinearly the Hall term creates spontaneously an X-point-like reconnection configuration, which enhances the reconnection rate nonlinearly, as does the electron pressure gradient. On the other hand, the electron pressure gradient is also responsible for imposing diamagnetic rotation and its stabilizing effect. We present high-resolution simulations in different regimes that show the impact of the various terms leading to either explosive behavior or nonlinear stabilization. In addition, we will also present first simulation results for the nonlinear evolution of m=1 tearing modes in a reverse field pinch configuration.

[1]Center for Integrated Computation and Analysis of Reconnection and Turbulence (CICART) and Center for Magnetic Self-Organization (CMSO), Univ. of New Hampshire.

TP8.00020 Investigation of Current Sheet Instabilities Using a GKE/FKI Particle Simulation Model , YU LIN, XUEYI WANG, Auburn University, LIU CHEN, ZHIHONG LIN, WENLU ZHANG, University of California, Irvine — The instability of current sheet under finite guide field (B_y) is investigated using our new gyrokinetic (GK) electron and fully kinetic (FK) ion particle simulation code, which resolves wave modes ranging from Alfvén waves to lower-hybrid/whistler waves. Compared with full-particle codes, the rapid electron cyclotron motion is removed in this model, while the realistic mass ratio m_e/m_i, finite electron Larmor radii, and wave-particle interactions are kept. The computation power is significantly improved. The preliminary simulation of Harris sheet is carried out in the 2D yz plane, with z being along the current sheet normal and anti-parallel B_x perpendicular to the simulation plane. The simulation has been performed with both a linearized (δf) GKe/FKi code and the nonlinear code, for $B_y/B_x = 0.1$-10. Under very small B_y, our results show LHDI modes at the current sheet edge propagating mainly in the y direction, as seen in previous simulations. As B_y increases, $k_\perp$ and diamagnetic drift direction shift away from the current flow direction y. The LHDI modes become weaker while high frequency modes stronger. In the cases with a large B_y, the LHDI modes evolve to a globally propagating instability, and multiple ion cyclotron modes are excited. A more complete 3D simulation is planned to investigate the new physics introduced by the large guide field.

TP8.00021 Lower-hybrid-drift instabilities in current-sheet equilibriumin in presence of a guide field , WENLU ZHANG, ZHIHONG LIN, LIU CHEN, University of California, Irvine, YU LIN, XUEYI WANG, Auburn University — Drift instabilities in one-dimensional current-sheet configuration in presence of a guide magnetic field, with lower-hybrid frequencies, are investigated. Nonlocal two-fluid stability analysis is carried out, and a class of unstable modes with multiple eigenstates are found by numerical means. It is found that the most unstable modes correspond to quasi-electrostatic, short-wavelength perturbations in the lower-hybrid frequency range, with wave functions localized at the edge of the current sheet where the density gradient is maximum. It is also found that there exist quasi-electromagnetic modes located near the center of the current sheet where the current density is maximum, with both kink- and sausage-type polarizations. These modes are low-frequency, long-wavelength perturbations. It turns out that the current-driven modes are low-order eigensolutions while the lower-hybrid-type modes are higher-order states, and there are intermediate solutions between the two extreme cases. Attempts are made to interpret the available simulation results.

TP8.00022 Development of an ion source and plasma injection system for a non-neutral plasma using radioactive ions , BRYAN G. PETERSON, DAVID K. OLSON, KELLEN M. GIRAUD, GRANT W. HART, Brigham Young University — We are building an ion trap to study the decay of ionized beryllium-7, an isotope with a 53-day half life (for neutral atoms). Because of the short half life of this isotope it is necessary to frequently change the source. We have designed a modified MeVVA (metal vapor vacuum arc) source which allows us to replace the source target material in a relatively short time so that fresh targets can always be used. We have also designed a quadrupole mass filter/ion injector to transport the desired beryllium-7 ions from the source in a low B-field region into the high-field trapping region while rejecting undesirable ions such as boron and carbon. The design of the source and ion injection system will be discussed and results from testing will be presented.

TP8.00023 Modeling the FTICR-MS signal of a ^{7}Be Ion Plasma , M. TAKESHI NAKATA, GRANT W. HART, BRYAN G. PETERSON, ROSS L. SPENCER, Brigham Young University — Beryllium-7 (^{7}Be) decays only by electron capture into Lithium-7 (^{7}Li) with a half life of 53 days. As a result, changing its electronic structure will affect its decay rate. We desire to study the effect of ionization on its decay rate. We will do this by trapping a ^{7}Be ion plasma in a Malmberg-Penning Trap and measuring its and ^{7}Li's concentration as a function of time by using Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS). We use this ratio as a function of time to directly measure the decay rate of the confined ion plasma rather than using gamma detection. We have modeled these signals in a 2-dimensional electrostatic particle-in-cell (PIC) code. The two spectrum peaks coalesce at high densities and at low densities they can be resolved. We also plan to model ^{7}BeH$^+$ and ^{7}Li at high densities to see if we can differentiate between them. The preliminary results of these investigations will be presented.

TP8.00024 Finite temperature m=0 upper-hybrid modes in a non-neutral plasma, theory and simulation. , GRANT W. HART, M. TAKESHI NAKATA, ROSS L. SPENCER, Brigham Young University — Axisymmetric upper-hybrid oscillations have been known to exist in non-neutral plasmas and FTICR/MS devices for a number of years[1,2]. However, because they are electrostatic in nature and axisymmetric, they are self-shielding and therefore difficult to detect in long systems. Previous theoretical studies have assumed a zero temperature plasma. In the zero temperature limit these oscillations are not properly represented as a mode, because the frequency at a given radius depends only on the local density and is not coupled to neighboring radii, much like the zero temperature plasma oscillation. Finite temperature provides the coupling which links the oscillation into a coherent mode. We have analyzed the finite-temperature theory of these modes and find that they form an infinite set of modes with frequencies above $\omega_c^2 - \omega_p^2$. For a constant density plasma the eigenmodes are Bessel functions. For a more general plasma the eigenmodes must be numerically calculated. We have simulated these modes in our $r - \theta$ particle-in-cell code that includes a full Lorentz-force mover[3] and find that the eigenmodes correspond well with the theory.

[1] J.J. Bollinger, et al., Phys. Rev. A **48**, 525 (1993).
[2] S.E. Barlow, et al., Int. J. Mass Spectrom. Ion Processes **74**, 97 (1986).
[3] M. Takeshi Nakata, et al., Bull. Am. Phys. Soc. **51**, 245 (2006).

TP8.00025 Collisional Damping of Plasma Waves on a Pure Electron Plasma Column.[1] , M.W. ANDERSON, T.M. O'NEIL, UCSD — Collisional damping of electron plasma waves (Trivelpiece-Gould waves) on a magnetized pure electron plasma column is discussed. Damping in a pure electron plasma differs from damping in a neutral plasma, since there are no ions to provide a collisional drag on the oscillating electrons. A dispersion relation for the complex frequency, ω, is derived from Poisson's equation and the drift-kinetic equation with the Dougherty collision operator. This approximate Fokker-Planck operator conserves particle number, momentum, and energy, and also is analytically tractable. For large phase velocity, where Landau damping is negligible, the dispersion relation yields the complex frequency $\omega = (k_z\omega_p/k)[1+(3/2)(k\lambda_D)^2(1+i10\alpha/9)(1+i2\alpha)^{-1}]$, where ω_p is the plasma frequency, k_z is the axial wave number, k is the total wave number, λ_D is the Debye length, ν is the collision frequency and $\alpha \equiv \nu k/\omega_p k_z$. This expression spans uniformly from the weakly collisional regime ($\alpha \ll 1$) to the strongly collisional regime ($\alpha > 1$), matching onto fluid results in the latter limit. For comparison, note that in the weakly collisional regime, the damping rate is given by $\mathrm{Im}(\omega) = -4\nu k^2\lambda_D^2/3$, which is suppressed from the damping rate for the case of a neutral plasma [i.e., $\mathrm{Im}(\omega) \simeq -\nu$] by the small factor $(k\lambda_D)^2 \ll 1$.

[1] Supported by NSF grant PHY-0354979.

TP8.00026 Collisional and Radiative Relaxation of Antihydrogen.[1] , E.M. BASS, D.H.E. DUBIN, UCSD — Antihydrogen is produced in high-magnetic-field Penning traps by introducing antiprotons into a pure-positron plasma at cryogenic temperature T.[2,3] In the experimental regime, three-body recombination forms highly-excited atoms which exhibit classical guiding-center drift orbits.[4,5] Using energy transition rates obtained from a Monte-Carlo simulation, we track the collisional evolution of a distribution of atoms from binding energies near T to $U_c = e^2(B^2/m_ec^2)^{1/3}$, where atom dynamics is chaotic. While the flux through the kinetic bottleneck ($U = 4T$) is proportional to $T^{-9/2}$, data suggest that the flux at U_c (at a fixed time) does not scale strongly with T or magnetic field B. At U_c, radiation begins to take over as the principle energy-loss mechanism. Evolution due to radiation is tracked for a typical collisionally-evolved energy distribution to show that a small number of low-angular-momentum atoms radiate to the ground state rapidly, while others drop into slowly-radiating, circular orbits at intermediate energies.

[1] Supported by NSF PHY-0354979 and NSF/DOE PHY-0613740.
[2] G. Gabrielse et al., *Phys. Rev. Lett.* **89**, 213401 (2002).
[3] M. Amoretti et al., *Nature* **419**, 456 (2002).
[4] M.E. Glinsky and T.M. O'Neil, *Phys. Fluids B* **3**, 1279 (1991).
[5] F. Robicheaux and J.D. Hanson, *Phys. Rev. A* **69**, 010701 (2004).

TP8.00027 Theory and Simulation of Field Error Transport.[1] , D.H.E. DUBIN, UCSD — The rate at which a plasma escapes across an applied magnetic field B due to symmetry-breaking electric or magnetic "field errors" is revisited. Such field errors cause plasma loss (or compression) in stellarators, tokamaks,[2] and nonneutral plasmas.[3] We study this process using idealized simulations that follow guiding centers in given trap fields, neglecting their collective effect on the evolution, but including collisions. Also, the Fokker-Planck equation describing the particle distribution is solved, and the predicted transport agrees with simulations in every applicable regime. When a field error of the form $\delta\phi(r,\theta,z) = \varepsilon(r)e^{im\theta}\sin kz$ is applied to an infinite plasma column, the transport rates fall into the usual banana, plateau and fluid regimes. When the particles are axially confined by applied trap fields, the same three regimes occur. When an added "squeeze" potential produces a separatrix in the axial motion, the transport is enhanced, scaling roughly as $(\nu/B)^{1/2}\delta\phi^2$ when $\nu < \omega$. For $\omega < \nu < \omega_B$ (where ω, ν and ω_B are the rotation, collision and axial bounce frequencies) there is also a $1/\nu$ regime similar to that predicted for ripple-enhanced transport.[1]

[1] Supported by NSF grant PHY-0354979.
[2] H.E. Mynick, *Ph Plas* **13** 058102 (2006).
[3] Eggleston, *Ph Plas* **14** 012302 (07); Danielson et al., *Ph Plas* **13** 055706.

TP8.00028 Spatial Landau Damping of Diocotron Modes in Nonneutral Disc Plasmas.[1] , J.C. QUINN, D.H.E. DUBIN, UCSD — We study the $\mathbf{E}\times\mathbf{B}$ dynamics of a thin disc of charge confined in a cylindrical Penning trap. The axial extent (thickness) of the disc is assumed to be negligible. An eigenvalue equation for density perturbations of the form $\delta n(r)\exp(im\theta)$ is obtained by linearizing the 2d equations of motion. A complete set of eigenmodes can be found numerically for an arbitrary equilibrium density profile, and were found analytically for the special equilibrium density profile of a flattened spheroid that rotates rigidly. In general, for a given m there are a finite number of discrete (undamped) $\mathbf{E}\times\mathbf{B}$ drift eigenmodes, which are generalizations of diocotron modes. There is also an infinite continuum of eigenmodes, which can lead to spatial Landau damping of initial density perturbations. We find the damping rate using three methods: Landau contour integration, a conservation of canonical angular momentum argument, and by expressing an initial perturbation as a wave packet of continuum eigenmodes. The results of the three methods match closely. A preliminary analysis of the effects of non-zero temperature and length has also been done, and experiments to observe these modes are in progress.

[1]Supported by NSF grant PHY-0354979.

TP8.00029 Nonlinear Coupling of Plasma Waves Modified by Separatrix Dissipation[1] , A.A. KABANTSEV, C.F. DRISCOLL, T.M. O'NEIL, UCSD — Quantitative measurements of the nonlinear coupling of diocotron modes characterize both the expected conservative coupling term and a new term arising from separatrix dissipation. Here, the pure electron plasma columns have a controllable axial trapping separatrix created by an applied θ-symmetric wall "squeeze" voltage. Prior experiments[2] established that this separatrix 1) enables and damps the "Trapped Particle" diocotron mode, and 2) damps $m_\theta\neq 0$ $k_z\neq 0$ plasma modes; and, in combination with external θ-asymmetries, 3) damps $m\neq 0$ $k=0$ diocotron modes, and 4) causes enhanced bulk plasma expansion and loss. The present experiments observe the resonant interaction between the traditional $m=2$ $k=0$ diocotron mode and the $m=1$ TP diocotron mode. The initial parametric decay of $m=2$ into $m=1$ is adequately predicted by the conservative nonlinearity arising from the continuity equation. However, the late-time evolution clearly requires (and quantifies) a dissipative nonlinear term which is not yet understood theoretically. This same dissipative coupling is also observed for *non-resonant* interactions, as in bulk plasma transport from field errors.

[1]Supported by NSF grant PHY-0354979.
[2]A.A. Kabantsev and C.F. Driscoll, *Phys. Rev. Lett.* **97**, 095001 (2006).

TP8.00030 Phase-Coherent Measurement of Particle Distributions in Electron Acoustic Waves.[1] , C.F. DRISCOLL, F. ANDEREGG, R.B. LYNCH, UCSD — Phase-coherent velocity distribution functions $f(\mathrm{v}_z)$ are measured by Laser Induced Fluorescence, for standing "electron acoustic" waves in pure ion plasmas. These (mis-named) waves are the lower-frequency branch of standard electrostatic plasma waves, with phase velocity $\mathrm{v}_\phi\approx 1.3\bar{\mathrm{v}}$. The waves are necessarily nonlinear so as to flatten the distribution at v_ϕ, thereby voiding the otherwise strong Landau damping. Our measurements are performed on $m_\theta=0$, $m_z=1$ waves driven to moderately large amplitude, i.e. $e\delta\phi\geq 0.1T$. Received LIF photons are accumulated in 8 phase bins, according to the instantaneous received phase of the wall electric field. The phase-coherent $f(\mathrm{v}_z)$ shows 1) particle sloshing, $\delta\langle\mathrm{v}\rangle$, as expected; 2) phase reversal of δf at $\mathrm{v}=0$ and $\mathrm{v}=\mathrm{v}_\phi$, in general correspondence with the linear perspective of $\delta f=(\delta f_0/\partial\mathrm{v})/(\mathrm{v}-\mathrm{v}_\phi)$; and 3) plateaux around v_ϕ with velocity widths as expected from wave-trapping theory. Measurements will be compared to traveling wave trapping theory and to standing wave particle simulations.

[1]Supported by NSF grant PHY-0354979.

TP8.00031 Frequency Variability of Electron Acoustic Waves.[1] , F. ANDEREGG, D.H.E. DUBIN, T.M. O'NEIL, C.F. DRISCOLL, UCSD — "Electron Acoustic Waves" (EAW) are non-linear electrostatic plasma modes, with a phase velocity comparable to the thermal velocity[2] $\mathrm{v}_\phi\approx 1.3\bar{\mathrm{v}}$. EAWs can be excited in neutralized plasmas,[3] pure electron plasmas and pure ion plasmas. Here, we present measurements of the "thumb shape" dispersion relation of EAW and Trivelpiece-Gould (TG) plasma modes in a pure magnesium ion plasma. Near the end of the thumb ($r_p/\lambda_D<3$), modes can be excited at almost any frequency, contrasting with the theoretical dispersion relation. The surprise here is that an "off-resonant" drive readily modifies the velocity distribution so as to make the drive *resonant*. These plasma modes can also be excited by a chirped down frequency burst, similar to the one described by the Berkeley group.[4] The chirped excitation creates extreme modification of $f(\mathrm{v}_z)$, and can be tailored to support a plasma mode at almost any frequency. We also observe that the resonant frequency of both EAW and TG plasma modes decreases with mode amplitude, in a fully reversible manner; but this effect has no theoretical explanation.

[1]Supported by NSF grant PHY-0354979.
[2]F. Valentini et al., *Phys. Plas.* **13**, 052303 (2007).
[3]Sircombe et al., *Plas. Phys. Cont. Fus.* **48**, 1141 (2006).
[4]Bertsche et al., *Phys. Rev. Lett.* **91**, 265003 (2003).

TP8.00032 Antihydrogen Trapping with the ALPHA apparatus , NIELS MADSEN, Physics Department, Swansea University, ALPHA COLLABORATION — Cold antihydrogen was first produced in 2002. Precision comparison of hydrogen and antihydrogen, which remains the ultimate goal of these experiments, promises to be the most precise test yet of the CPT theorem. I.e. that hydrogen and antihydrogen must have the same spectrum at any level of precision. To make such tests possible the ALPHA collaboration have decided that the most promising route is to trap the antihydrogen. We describe the current state of the ALPHA endeavour, as well as the most recent results. One issue is whether magnetic traps, which are the key to trap the neutral antihydrogen are at all compatible with the penning traps used to store the charged species that make up the antiatoms. As quadrupole magnetic fields were at best, badly compatible with our envisaged schemes for antihydrogen, ALPHA uses a magnetic octupole to create the transverse magnetic field minimum necessary to trap antihydrogen. We have demonstrated that charged particles trapped in a superposed penning trap are stable in this field, it remains "only" to demonstrate antihydrogen formation, and ultimately trapping. The main challenge for the trapping seems at present to be that antihydrogen, using the current methods, tends to be formed at temperatures to high to allow trapping. ALPHA is currently working on a number of schemes to overcome this obstacle.

TP8.00033 HIGH POWER MICROWAVE AND LASER DRIVEN SOURCES —

TP8.00034 Magnetic Priming at the Cathode and Anode of a Relativistic Magnetron , B.W. HOFF, R.M. GILGENBACH, Y.Y. LAU, N.M. JORDAN, J.C. ZIER, M.R. GOMEZ, D.M. FRENCH, E.J. CRUZ, University of Michigan, K.L. CARTWRIGHT, M.D. HAWORTH, P.J. MARDAHL, T.A. SPENCER, Air Force Research Laboratory, D. PRICE, L-3 Communications — Magnetic priming[1,2] experiments on the UM/ L-3¬Titan relativistic magnetron (100 MW's in L-band, -300 kV, ∼3 kGauss), have shown suppression of unwanted modes and reductions in starting currents for the pi-mode. Data from continuing simulations and experiments on magnetic priming at the cathode will be presented, as well as data on magnetic priming at the cathode and anode. Data show that magnetic priming at the cathode significantly lowers (average factor of 2.5) the starting current for pi-mode generation. The percentage of pi-mode shots was also increased by magnetic priming at the cathode by as much as 60% over unprimed shots. Experiments and simulation results will be reported concerning the effects of magnetic priming at both cathode and anode. References [1] V.B. Neculaes, R.M. Gilgenbach, and Y.Y. Lau, US Patents 6,872,929 (3/29/2005) and 6,921,890 (7/26/2005); Appl. Phys. Lett., 83, 1983 (2003). [2] M.C. Jones, V.B. Neculaes, W. White, Y.Y. Lau, and R.M. Gilgenbach, Appl. Phys. Lett., 84, p1016, (2004) Acknowledgements: This research was supported by AFOSR, AFRL and the AFOSR-MURI Program on Cathode and Window Breakdown for High Power Microwave Sources

TP8.00035 Recent Advances in Magnetron Phase Locking: Effects of Frequency Chirps and Locking of Multiple Magnetrons[1] , EDWARD CRUZ, PHONGPHAETH PENGVANICH, YUE YING LAU, RONALD GILGENBACH, University of Michigan, Ann Arbor, MI, JOHN LUGINSLAND, NumerEx, Ithaca, NY, EDL SCHAMILOGLU, University of New Mexico, Albuquerque, NM — Phase-locking is utilized today in many important applications, ranging from small scale devices such as cardiac pacemakers to large scale devices such as radar. We have recently developed a magnetron-specific model [1] to qualitatively explain the various regimes observed in magnetron injection-locking experiments [2], which utilize two continuous wave oven magnetrons; one functions as an oscillator and the other as a driver. We have applied this model to study injection locking when the driver has a frequency chirp. The model has also recently been extended to analyze peer-to-peer locking of two magnetrons of comparable powers and frequencies. The feasibility of locking will be explored in terms of the variations in these parameters of the individual magnetrons, as well as the degree of coupling among them. Locking of a larger number of such magnetrons will be explored. A preliminary experiment is being conducted on the peer-to-peer locking of two oven magnetrons. [1] P. Pengvanich, et al., J. Appl. Phys. **98**, 114903 (2005). [2] V. B. Neculaes, Ph.D. Dissertation, U. Michigan, Ann Arbor, MI (2005).

[1]This research was supported by ONR/UNM, AFRL, and AFOSR.

TP8.00036 Metal-Oxide-Junction, Triple-Point Cathodes for High Current Vacuum Electron Devices[1] , NICHOLAS JORDAN, RON GILGENBACH, Y.Y. LAU, BRAD HOFF, DAVID FRENCH, PHONGPHAETH PENGVANICH, University of Michigan, Nuclear Engineering and Radiological Science — Recent experiments at the University of Michigan have fabricated metal-oxide junction cathodes consisting of hafnium oxide coatings over stainless steel substrates. High dielectric constant HfO_X coatings are deposited by ablation-plasma-ion lithography using a KrF laser at 248 nm and 3-40 J/cm2 fluence. Experiments were performed on a relativistic magnetron driven by the Michigan Electron Long-Beam Accelerator at voltages of -300 kV, currents of 1-15 kA, and pulse-lengths of 0.3-0.5 ms. Experiments tested four patterned arrays of HfO2 islands on stainless steel cathodes. Three baseline comparison cases were run: fully dielectric coated, bare metal, and metal-only islands. Experimental data show initial peak currents for cathodes patterned with HfO_X islands, reached an average of 6 kA, 60% larger than uncoated cathodes. Current turn-on and rise time are also significantly faster for the patterned arrays of HfO_X.

[1]Research supported by the AFOSR-MURI, L-3 Comm., and Northrop Grumman. N.M.J. is also supported by an Applied Materials Graduate Fellowship.

TP8.00037 Electric field and electron orbits near a triple point , DAVID M. FRENCH, NICHOLAS M. JORDAN, Y.Y. LAU, R.M. GILGENBACH, P. PENGVANICH, University of Michigan — Triple point, defined as the junction of metal, dielectric, and vacuum, is the location where electron emission is favored in the presence of a sufficiently strong electric field. In addition to being an electron source, the triple point is generally regarded as the location where flashover is initiated in high voltage insulation, and as the vulnerable spot from which rf breakdown is triggered. In this paper, we focus on the electric field distribution at a triple point of a general geometry, as well as the electron orbits in its immediate vicinity. We calculate the orbit of the first generation electrons, the seed electrons. It is found that [1], despite the mathematically divergent electric field at the triple point, significant electron yield most likely results from secondary electron emission when the seed electrons strike the dielectric. The analysis gives the voltage scale in which this electron multiplication may occur. It also provides an explanation on why certain dielectric angles are vulnerable to electron multiplication over others, as observed in previous experiments [1]. This work was supported by AFOSR.
[1] N. M. Jordan et al., J. Appl. Phys. (in press, 2007)

TP8.00038 Electric field distribution on knife-edge field emitters , RYAN MILLER, University of Wisconsin, YUE YING LAU, University of Michigan, JOHN BOOSKE, University of Wisconsin — Of critical importance to advanced High Power Microwave (HPM) generators is the development and understanding of robust cold cathodes with low turn-on electric fields. Recent interesting candidates include ridged metallic cathodes fabricated by either laser ablation or other microfabrication methods [1]. We use conformal mapping to calculate the electric field on a knife-edge cathode. We find that the field enhancement factor scales approximately as the square root of the height-width ratio of the knife-edge [2]. An analytic approximation for the divergent electric field in the immediate vicinity of the sharp edge is derived. A smaller knife-edge placed on top of a larger one demonstrates that the composite field enhancement factor is approximately equal to the product of the field enhancement factor of the individual knife-edges. This proves the conjecture [3] on multiplication of field enhancement factors for one special case. This work was supported by AFOSR/MURI and by AFRL.
[1] M.C. Jones, et al, Rev .Sci.Instrum.,75, 2976 (2004)
[2] R. Miller, Y. Y. Lau, J. H. Booske, Appl. Phys. Lett., (to be published)
[3] W. Schottky, Z. Physik, 14, 63 (1923).

TP8.00039 Effect of Random Circuit Fabrication Errors on Small Signal Gain and Phase in Helix Traveling Wave Tubes , P. PENGVANICH, University of Michigan, Ann Arbor, D.P. CHERNIN, SAIC, McLean, VA 22102, Y.Y. LAU, University of Michigan, Ann Arbor, J.W. LUGINSLAND, NumerEx, Ithaca, NY 14850, R.M. GILGENBACH, University of Michigan, Ann Arbor — Motivated by the current interest in mm-wave and THz sources, which use miniature, difficult-to-fabricate circuit components, we evaluate the statistical effects of random fabrication errors on a helix traveling wave tube amplifier's small signal characteristics. The small signal theory is treated in a continuum model in which the electron beam is assumed to be monoenergetic, and axially symmetric about the helix axis. Perturbations that vary randomly along the beam axis are introduced in the dimensionless Pierce parameters b, the beam-wave velocity mismatch, C, the gain parameter, and d, the cold tube circuit loss. Our study shows, as expected, that perturbation in b dominates the other two. The extensive numerical data have been confirmed by our analytic theory. They show in particular that the standard deviation of the output phase is linearly proportional to standard deviation of the individual perturbations in b, C, and d. Simple formulas have been derived which yield the output phase variations in terms of the statistical random manufacturing errors. This work was supported by AFOSR and by ONR.

TP8.00040 Two-Dimensional Axisymmetric Child-Langmuir Scaling Law[1] , BENJAMIN RAGAN-KELLEY, JOHN VERBONCOEUR, University of California Berkeley — The classical one-dimensional Child-Langmuir law has been extended to two dimensions by numerical simulation in planar geometries [1]. By considering an axisymmetric cylindrical system with emission radius r, outer radius $R > r$, and gap length L, we further examine the space charge limit in two dimensions. The ratio of the observed current density limit J_{CL2} to the theoretical one-dimensional value J_{CL1} is found to be a monotonically decreasing function of the ratio of emission area (r^2) to gap separation (L). This result is in agreement with the planar results, where the emission area is proportional to the cathode width (r) [1]. The simulations were run in the particle in cell code, OOPIC [2]. [1] J. W. Luginsland, Y. Y. Lau, and R. M. Gilgenbach, Phys. Rev. Lett. 77, 4668 (1996). [2] J. P. Verboncoeur, A. B. Langdon, and N. T. Gladd, Comp. Phys. Comm. 87, 199 (1995).

[1]This work supported in part by AFOSR Cathodes and Breakdown MURI04 grant FA9550-04-1-0369, AFOSR STTR Phase II contract FA9550-04-C-0069, and the Air Force Research Laboratory, Kirtland.

TP8.00041 Effect of abrasive surface roughening on the secondary yield of various metals , TIMOTHY GRAVES, The Aerospace Corporation — The secondary electron yield of metallic conductors plays a critical role in the development of multipactor discharges. These discharges require a secondary yield greater than unity at the appropriate energy level for sustained breakdown. By reducing the secondary yield below unity in the necessary energy range, multipactor and multipactor-induced glow discharges can be eliminated. Surface roughening has been shown to successfully lower the secondary yield to below unity (ref. 1). In addition, abrasive bead blasting has been shown to effectively reduce the secondary yield of copper surfaces while preserving voltage breakdown characteristics (ref. 2). This study investigates the effect of abrasive surface roughening on the secondary yield of materials such as copper, aluminum, and stainless steel. In addition to measuring the change in the secondary yield as a function of abrasive particle size, the multipactor resistance and voltage breakdown characteristics are investigated. In addition, the effect of vacuum conditioning via multipactor and rf plasma cleaning on the roughened surfaces will be discussed.
Ref. 1. H. Bruining. Physics and Applications of Secondary Electron Emission. McGraw-Hill, NY, 1954.
Ref. 2. T. P. Graves, Ph.D. Thesis, MIT. 2007

TP8.00042 Formation of regular filamentary plasma arrays generated by a 1.5 MW, 110 GHz gyrotron[1] , Y. HIDAKA, E.M. CHOI, I. MASTOVSKY, M.A. SHAPIRO, J.R. SIRIGIRI, R.J. TEMKIN, Plasma Science and Fusion Center, Massachusetts Institute of Technology — We report the achievement of self-initiated breakdown of a volume of air at atmospheric pressure with a focused Gaussian beam generated by a pulsed gyrotron. The relevant parameters of the beam are the frequency of 110 GHz, pulse length of 3 microseconds, maximum peak power of 1.5 MW, and peak power density of 2.5 MW/cm^2. Regular two-dimensional arrays of plasma filaments, similar to those observed in our previous experiments on air breakdown at the surfaces of dielectric windows, were also present in the open-shutter images of volume breakdown. Patterns observed in volume breakdown allowed us to deduce that the formation of the array can be explained as a progressive development of each filament due to diffraction from each existing filament resulting in field enhancement approximately a quarter wavelength upstream of the filament. Electromagnetic wave simulations strongly corroborate this explanation. Further breakdown experiments will be also conducted in different pressures and gases in the near future.

[1]This research was supported by the US AFOSR MURI04 program on the Nano-Physics of High Current Density Cathodes and Breakdown.

TP8.00043 Initial Operation of a Wideband 140 GHz, 1kW Confocal Gyro-Traveling Wave Amplifier[1] , COLIN JOYE, MICHAEL SHAPIRO, RICHARD TEMKIN, JAGADISHWAR SIRIGIRI, ANTONIO TORREZAN, Massachusetts Institute of Technology — The present experimental results of a zero-drive stable, short pulse 140 GHz gyro-traveling wave tube amplifier are reported. The amplifier consists of three amplifying sections employing a novel high order HE(0,6) operating mode of a quasi-optical confocal waveguide in order to reduce mode density and achieve circuit loss through diffraction rather than absorption in localized dielectric materials. The confocal waveguide preferentially provides higher loss to the lower order competing modes thus allowing operating in a higher order mode. Two quasi-optical severs are used to suppress backward wave oscillations. At present, the amplifier has achieved a linear gain of 34 dB in experiment, and peak output powers up to 400W have been observed at a beam voltage of 39.5kV, beam current of 1.65A, and beam pitch factor of 0.9. Bandwidths over 1 GHz have been observed.

[1]This project is supported by NIBIB grant #5R01EB1965.

TP8.00044 A Cusp Gun Gyro-TWA with Helical Waveguide Interaction Region , CRAIG ROBERTSON, DAVID ROWLANDS, COLIN WHYTE, ALAN YOUNG, WENLONG HE, ADRIAN CROSS, ALAN PHELPS, KEVIN RONALD, The University of Strathclyde — The latest results of experimental and numerical investigations of an X-band gyro-TWA with a cusp gun and a helically corrugated interaction region are presented. A helically corrugated waveguide radically alters the dispersion relation of the interacting mode such that it matches the electron beam dispersion over a broad frequency range at close to zero axial wavenumber. Gyro-amplifiers require relativistic electron beams with low velocity spread and with a high fraction of the electron energy associated with the cyclotron motion. For harmonic operation and mode control an axis-encircling beam is desirable. A cusp gun was used to produce an axis-encircling beam by passing an annular beam through a magnetic cusp, introducing an azimuthal rotation. The passage of an electron beam through a non-adiabatic magnetic field reversal converted part of the electron beam's axial velocity into axis-encircling transverse velocity. Experiments were carried out using a field emission cathode and proved highly successful with a 120keV, 37A azimuthally rotating annular beam being formed. Microwave radiation in the frequency range of 8.4Hz to 10.4GHz was produced, with an output power 1.1MW at a frequency of 9.4GHz, corresponding to a saturated gain of 35dB and a measured efficiency of 25%.

TP8.00045 A High Power High Frequency Maser Based on a Two-Dimensional Structure , LORNA FISHER, IVAN KONOPLEV, ADRIAN CROSS, ALAN PHELPS, University of Strathclyde — High power millimetre-wave sources operating in the W-band (75GHz-110GHz) frequency range are important for a number of applications. In order to achieve the desired high power coherent radiation, the use of an oversized annular electron beam is suggested. This will allow problems associated with high electromagnetic power density inside the interaction space (such as millimetre-wave pulse shortening) to be overcome. A 2D periodic lattice will be used to synchronize the radiation from different parts of the oversized electron beam as well as to ensure spatial and temporal coherence of the radiation. There are a number of radiation sources capable of generating continuous millimetre-wave radiation at MW power levels. Analysis of different beam-wave interaction mechanisms used to produce the radiation will be presented. Various models will be studied and compared for suitability for single mode operation at high frequency and power. The design of a high power source based on the optimum beam wave interaction mechanism for operation in the W-band frequency region will be presented.

TP8.00046 Development of Multi-Frequency (105-140) GHz Gyrotron , ALEXANDER LITVAK, GRIGORIY DENISOV, Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia, VADIM MYASNIKOV, VADIM NECHIPORENKO, EVGENII TAI, VLADIMIR ZAPEVALOV, GYCOM Ltd., Nizhny Novgorod, Russia — The paper presents last time achievement in the development of a step tunable multi-frequency gyrotron with a megawatt power level. The mock-up of such gyrotron with a new principle broadband electrodynamics system containing Brewster output window was successfully tested. In the frequency range (100-150) GHz the generation of power exceeding 1 MW was demonstrated at 6 frequencies with a very low (about 2%) internal diffraction losses. On the basis of this result industrial gyrotron with a CVD diamond output window was constructed for 10 sec operation. The full time tests are planned for September 2007.

TP8.00047 Vortex structures in relativistic magnetrons[1] , JOHN DAVIES, JING ZHOU, CHIPING CHEN, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139 — We showed recently the existence of vortex flows in the electron beam equilibria of magnetron structures consisting of a central cylindrical cathode and a periodically corrugated cylindrical anode [J. A. Davies and C. Chen, Phys. Plasmas 13, 012310 (2006)]. In this paper, we present a relativistic treatment of the equilibrium of a planar magnetron consisting of a planar cathode and a corrugated anode. The electron density in the electron layer is assumed to be constant, and guiding-center approximation is employed. Properties of the equilibrium such as the electrostatic potential, flow velocity, and the self-magnetic field are determined analytically. An interesting result of the present analysis is the appearance of vortex structures near the cathode. Test particle studies are carried out to identify the parameter regimes in which the guide-center approximation is valid. Progress in determining if these parameters regimes and our results are relevant to relativistic magnetron operation will be discussed.

[1]Research supported by AFOSR.

TP8.00048 Small-Signal Gain Theory of a Planar Magnetron[1] , JING ZHOU, CHIPING CHEN, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139 — A planar magnetron model is developed to analyze the small-signal theory of a magnetron. The analysis includes a full Floquet expansion and fully electromagnetic effects. The present planar model avoids the problem of multiple poles (singularities) and the model is a good approximation, provided that the A-K gap is small compared with the cathode radius. An analytical dispersion relation of such a planar magnetron is derived and the growth rate is calculated based on the dispersion relation. MAGIC2D simulations are performed on the planar magnetron. The simulated growth rate is found in good agreement with the theoretical prediction.

[1]This research was supported by the Air Force Office of Scientific Research, Grant No. FA9550-06-1-0269.

TP8.00049 RF Modes in the Saturated Stage of a Magnetron[1] , D.J. KAUP, University of Central Florida — Theoretical studies of the cold-fluid model of crossed-field electron vacuum devices such as magnetrons and crossed-field amplifiers have shown that there are two important stages to their operation [1]. First there is the "initiation stage" wherein an instability in the rf fields grows. When this instability saturates, the device enters into the "saturation stage." In this stage, there are the two slow modes from the initiaion stage, and three additional fast modes. One of these fast modes is the drift (diocotron) resonance. The other two modes are cyclotron modes. Whence the equations for this system is a fifth order set of ODE's. Theory [1] has outlined the major features of the drift resonance in the saturation stage. However a complete understanding of it and the contributions of the cyclotron modes require a study of numerical solutions. In the saturation stage there are five rf modes; the original two modes of the initiation stage and three additional fast modes with fast vertical oscillations on the order of 100-1000 times that of the initiation rf modes. We will present numerical solutions of these rf modes in the saturation stage, discuss their implications and how these solutions differ from those of the initiation stage.
[1] D.J. Kaup, Phys. Plasmas **13**, 053113 (2006).

[1]Research supported in part by the AFOSR.

TP8.00050 Phase-matched even harmonic generation in relativistic ionization fronts , FREDERICO FIUZA, RICARDO FONSECA, LUIS SILVA, GoLP/Centro de Física dos Plasmas, Instituto Superior Técnico, Lisboa, Portugal — Relativistic harmonic generation in plasmas is an active field of research. Generating harmonics efficiently is still a challenge, mainly due to the difficulties in guaranteeing phase-matching in the conversion process over long interaction lengths. We present a novel scheme to generate phase-matched even harmonics in relativistic ionization fronts. The magnetic mode induced in the collision of e.m. radiation with relativistic ionization fronts, driven by an ultra-intense laser pulse propagating in a gas target, is used to generate even harmonics of the laser pulse. By controlling the frequency of the incident radiation the conversion process can be phase-matched. This scheme also provides a means of indirect detection and characterization of the magnetic mode, which was never observed experimentally. Our theoretical model predicts the phase-matching conditions and describes the amplitude evolution of the generated even harmonics. In order to check the validity of the model, detailed 1D and 2D PIC simulations were preformed with OSIRIS 2.0. The analysis reveals a good agreement between the theoretical model and the simulation results. The conversion efficiency of the process was also studied, indicating the possibility of achieving controlled highly efficient even harmonic generation.

TP8.00051 Interaction of intense lasers with nanostructured plasmas , JOANA MARTINS, FABIO PEANO, LUíS GARGATÉ, RICARDO FONSECA, LUíS SILVA, GoLP/CFP Instituto Superior Técnico, Lisboa, Portugal — Radiation generation from the interaction of intense laser pulses with solid density nanostructured plasmas is analyzed using PIC (two and three-dimensional) simulations performed with OSIRIS 2.0. The role of the relativistic electron dynamics on radiation generation is considered. The influence of the nanostructural design of different targets is studied through simulations, and the generation of radiation is optimized for different target periodicities and densities. Simulations show that the target properties allow for the spectral control of the radiated energy. The simulation results are compared with a theoretical model that takes into account the relativistic electron dynamics in the presence of the laser and the periodic self-consistent fields from the high (ion) charge density regions in the target.

TP8.00052 Soft X-ray radiation measured by four-segment vacuum photodiode , JIRI SCHMIDT, KAREL KOLACEK, OLEKSANDR FROLOV, VACLAV PRUKNER, JAROSLAV STRAUS, Institute of Plasma Physics, v.v.i., AS CR, Za Slovankou 3, 182 00 Prague — A soft X-ray diode is a strong diagnostic tool for system alignment, among others, in capillary discharge experiments, which generate directional soft x-ray radiation, eventually a laser pulse. In our experimental capillary discharge devices we usually used PIN diode or vacuum photodiode (one-segment). These diagnostics are not suitable, mainly because many shots (more than 50) are necessary to find the optical axis. Last year we designed and manufactured a four-segment soft X-ray vacuum photodiode with a golden photocathode, which detects the soft X-ray radiation emitted from our capillary discharge devices in the axial direction. This new vacuum photodiode is capable to locate the soft X-ray laser axis in a few shots (less than 10). The description and the experimental measurement of the four-segment soft X-ray vacuum diode will be presented.

TP8.00053 Fast capillary discharge facility CAPEX-U as a source of the soft X-ray radiation , OLEKSANDR FROLOV, KAREL KOLACEK, JIRI SCHMIDT, VACLAV PRUKNER, JAROSLAV STRAUS, Institute of Plasma Physics, v.v.i., AS CR, Za Slovankou 3, 182 00, Prague — Capillary discharges are more perspective resources for lasing in soft x-ray region than other media (free electron lasers, synchrotron sources, harmonic up-conversion of high power visible/IR lasers). After successful experiments on CAPEX device with lasing on Ne-like Ar ($\lambda =$ 46.9 nm) we report on our apparatus CAPEX-U (CAPillary EXperiment Upgrade) with larger transversal dimensions, with transparency along its axis, and with multichannel laser-triggered spark gap, which enables exact synchronization of the detectors and attached experiments. Our motivation for building such new apparatus was not only lasing on Ne-like argon, but also testing a feasibility of amplification at shorter wavelengths (below 20 nm). This paper presents the description of the CAPEX-U apparatus, and the results of axial soft X-ray spectroscopic measurements of the pulsed high-current capillary discharge.

TP8.00054 Possibility of an H-like N recombination laser at 13.39 nm excited by capillary discharge , YUSUKE SAKAI, SHUNSUKE TAKAHASHI, MASATO WATANABE, AKITOSHI OKINO, EIKI HOTTA, Tokyo Institute of Technology — A capillary discharge soft X-ray laser is fascinating in its high efficiency due to direct energy conversion from the electrical discharge energy and spatial coherence taking advantage of the long plasma column. In order to shorten the wavelength of the laser and to put it into practical use, possibility of the lasing of an H-like N recombination 13.39 nm laser, which can be focused by using a Mo/Si multi-layer mirror, is investigated. Population inversion between principal quantum numbers n=2 and n=3 might be generated in the expansion phase after the maximum pinch utilizing fast pulsed current amplitude of over 50 kA with pulse width of about 100 ns. Temporal radiation intensity from the nitrogen plasma column is measured using a x-ray photo diode to evaluate optimum plasma parameter required to realize a 13.39 nm laser.

TP8.00055 Relic crystal lattice effects on Raman compression of powerful x-ray pulses in plasmas[1] , VLADIMIR MALKIN, NATHANIEL FISCH, Princeton University — Powerful x-ray pulses might be compressed to even greater powers by means of backward Raman amplification in ultradense plasmas produced by ionizing condensed matter by the same pulses. The pulse durations contemplated are shorter than the time for complete smoothing of the crystal lattice by thermal motion of ions. Although inhomogeneities are generally thought to be deleterious to the Raman amplification, the relic lattice might in fact be useful for the Raman amplification. Caused by the lattice, the x-ray frequency band gaps can suppress parasitic Raman scattering of amplified pulses, while enhanced dispersion of x-ray group velocity near the gaps can delay self-phase modulation instability and also enable an extra amplification of x-rays in a way similar to the chirped pulse amplification technique.

[1]This work was supported in part by the NNSA under the SSAA Program through DOE Research Grant No. DE-FG52-04NA00139.

TP8.00056 High Power Picosecond Laser Pulse Recirculation for Compton Scattering[1] , M. SHVERDIN, S. ANDERSON, C. BROWN, S. BETTS, D. GIBSON, J. HERNANDEZ, M. JOHNSON, I. JOVANOVIC, D. MCNABB, M. MESSERLY, J. PRUET, A. TREMAINE, F. HARTEMANN, C. SIDERS, C.P.J. BARTY, LAWRENCE LIVERMORE NATIONAL LAB TEAM — Gamma-ray generation by Compton back-scattering laser photons off a relativistic electron beam suffers from a small Thomson cross-section. Recirculating unused laser photons can increase the average gamma-ray flux. Traditional approaches to laser recirculation rely on either resonant coupling of a low-energy pulse train to a cavity or active pulse switching using a pockels cell. Our alternative, passive approach does not require interferometeric alignment accuracy and is compatible with ultrashort, high peak power pulses. Pulse injection is achieved by a thin frequency converter inside the cavity in the path of the incident beam. The cavity consists of dichroic mirrors that transmit the incident but reflect the frequency-converted light. Initial modeling and experiments predict better than 20 times increase in the average brightness of Compton back-scattering sources with our pulse recirculation method.

[1]This work was performed under auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7504-Eng-48.

TP8.00057 Evolution of FEL-produced plasma with photoionized electron two-stream instability[1] , I.A. ANDRIYASH, V. YU. BYCHENKOV, P.N. Lebedev Physics Institute, RAS, Moscow, Russia, W. ROZMUS, University of Alberta, Edmonton, Alberta, Canada — Plasmas created in the interaction of X-ray laser pulse of a free electron laser (FEL) with gaseous medium display a number of specific properties that are substantially different from characteristics of plasmas produced by optical lasers. An electron distribution function in the FEL-photoionized plasma is anisotropic and monoenergetic or multi-monoenergetic depending on the material. These features make these plasmas unstable with respect to photoionized electron two-stream (PITS) instability. In this paper we represent a kinetic non-stationary theory of PITS instability of a weakly ionized plasma which takes into account an electron production due to photo-effect through the interaction of an ultrashort linearly polarized X-ray FEL pulse with a gas jet, growth of unstable quasistatic electric field, and wave damping and electron distribution relaxation due to electron collisions with atoms. Our theory is based on the integral kinetic equation for correlation function of electron density fluctuations. The evolution and relaxation of PITS instability is illustrated by an example of He gas-jet ionized by EUV pulse of FEL with different pulse durations for typical gas-jet pressures.

[1]This work was partially supported by Russian Foundation for Basic Research (Grant No. 06-02-16103) and the Natural Sciences and Engineering Research Council of Canada.

TP8.00058 Commissioning of a high-brightness photoinjector for Compton scattering x-ray sources[1] , SCOTT ANDERSON, DAVID GIBSON, MIKE MESSERLY, MIROSLAV SHVERDIN, AARON TREMAINE, FRED HARTEMANN, CRAIG SIDERS, CHRISTOPHER BARTY, Lawrence Livermore National Laboratory, HRISTO BADAKOV, PEDRO FRIGOLA, BRENDAN O'SHEA, JAMES ROSENZWEIG, UCLA Dept. of Physics and Astronomy — Compton scattering of intense laser pulses with ultra-relativistic electron beams has proven to be an attractive source of high-brightness x-rays with keV to MeV energies. This type of x-ray source requires the electron beam brightness to be comparable with that used in x-ray free-electron lasers and laser and plasma based advanced accelerators. We describe the development and commissioning of a 1.6 cell RF photoinjector for use in Compton scattering experiments at LLNL. Injector development issues such as RF cavity design, beam dynamics simulations, emittance diagnostic development, results of sputtered magnesium photo-cathode experiments, and UV laser pulse shaping are discussed. Initial operation of the photoinjector is described and transverse phase space measurements are presented.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

TP8.00059 Design and Initial Operation of a Tunable Compton-Scattering Based Gamma-Ray Source[1] , DAVID GIBSON, SCOTT ANDERSON, SHAWN BETTS, MICAH JOHNSON, DENNIS MCNABB, MIKE MESSERLY, JASON PRUET, MIROSLAV SHVERDIN, AARON TREMAINE, FRED HARTEMANN, CRAIG SIDERS, CHRIS BARTY, Lawrence Livermore National Laboratory — Tunable, monochromatic gamma-ray sources are currently being developed at LLNL for nuclear photo-science and related applications. These novel systems are based on Compton scattering of laser photons by a high brightness relativistic electron beam produced by an rf photoinjector and offer a path to high-brightness high-energy ($>$ 1 MeV) x-ray & gamma-rays due to their favorable scaling with electron energy. The current demonstration source, called the "Thomson-Radiated Extreme X-Ray" (T-REX) source, targets photon energies up to 1 MeV. With extensive modeling using PARMELA and well-benchmarked custom Compton-scattering simulation codes, the optimal design parameters for an interaction (including factors such as the collision angle, focal spot size, bunch charge, laser intensity, pulse duration, and laser beam path) can be determined. Here we present the results of this optimization, including early experimental results from the newly commissioned system.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

TP8.00060 NSTX SPERICAL TORUS —

TP8.00061 Overview of NSTX Research Facility and Recent Experimental Results.[1] , MASAYUKI ONO, Princeton University, NSTX TEAM — The 2007 NSTX experimental campaign yielded significant new experimental results in many science areas. Measurements of the turbulent electron fluctuation spectrum made over a wide range of plasma conditions including H-mode, L-mode, and reversed shear plasmas using the high-k microwave scattering system which is capable of local measurements of electron scale turbulence with MHz bandwidth. RWM feedback control has been explored at high beta with and without error field correction. The upgraded lithium evaporator was used to improve the plasma confinement and increase Te in H-mode plasmas. With lithium evaporation, a significant increase in the Electron Bernstein waves emission was observed in H-mode plasmas at high elongation. For the first time, beta suppression of Alfven cascades was documented and the beta-induced Alfven acoustic eigenmode was observed at high beta. Deuterium puffing has been used to demonstrate partial divertor detachment in highly shaped plasmas with little confinement deterioration. A record electron temperature of 4.7keV was achieved on NSTX using HHFW current drive phasing.

[1]This work supported by DoE Contract No. DE-AC02-76CH03073

TP8.00062 Effects of Evaporated Lithium Coatings on Plasma-Facing Surfaces in NSTX[1] , M.G. BELL, R.E. BELL, R. KAITA, H.W. KUGEL, B.P. LEBLANC, R. MAJESKI, D.K. MANSFIELD, J.E. MENARD, S.F. PAUL, J.A. ROBINSON, H. SCHNEIDER, C.H. SKINNER, J.R. TIMBERLAKE, PPPL, AND THE NSTX TEAM — An evaporator has been used to apply lithium to the carbon tiles on the lower divertor in NSTX at rates up to 70mg/min. Numerous lithium depositions were performed in the 2007 operating period, ranging from about 10mg to 2g but typically 200 - 300mg of lithium prior to a discharge. The lithium evaporation continued through the 5 - 10 min. of helium glow discharge cleaning usually applied before each shot and during the tokamak discharge as well, which distributed the lithium more widely than line of sight. Examination of the divertor tiles after the experiments showed migration of the lithium away from the strike-points. The effects of lithium were studied over a range of plasma conditions. In 1MA, 0.45T, H-mode plasmas with 4MW NBI, there was an increase of about 20% in the electron and 10% in the total stored energy and ELM activity was reduced or suppressed after lithium. This was accompanied by increasing impurity radiation from the core which sometimes limited performance. Contrary to previous experience, the effects of the lithium coating could persist for several discharges after application.

[1]Supported by US DOE contract no. DE-AC02-CH03073

TP8.00063 NSTX conditioning experiment using injected lithium powder , DENNIS MANSFIELD, Princeton Plasma Physics Laboratory, NSTX TEAM — An attempt was made to condition the plasma facing components of NSTX by injecting Li powder. The injection was carried out using the existing lithium pellet injector with a modified sabot design. The 50 micron diameter powder was injected into several discharges while its effects were evaluated on each subsequent discharge. A discussion of the effects of this experiment will be presented. This work was supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00064 Effects of Lithiumization of Electron Temperature and Density Profiles , B.P. LEBLANC, Princeton Plasma Physics Laboratory, NSTX TEAM — NSTX conducted an aggressive first wall conditioning campaign during which up to 100 g of lithium was evaporated progressively inside the vacuum vessel. This work will search for change in the behavior of n_e and T_e profiles measured by Thomson scattering. Casual observation during the earlier phase of the lithiumization did not reveal significant changes, but a systematic search will be done for the preparation of this paper. Contrary to last year's results, the effects of this more aggressive lithiumization appear to last longer; increase in stored energy and reduction of ELM activity have been observed, sometimes accompanied by core impurity accumulation. Further analysis will attempt to correct the part of the Thomson scattering data which was affected by window coating during the last month of plasma operation. This work is supported by United States DOE contract DE-AC02-76CH03073.

TP8.00065 Measurements of radiated power during LiTER operation in NSTX[1] , STEPHEN PAUL, Princeton Plasma Physics Laboratory, NSTX RESEARCH TEAM — Lithium vapor was injected into the NSTX vacuum vessel by heating lithium in a stainless steel oven that was placed in close proximity to the plasma facing components during the 2007 experimental campaign. Low-Z coating experiments using carbonization, boronzation, an lithium pellets have been used for many years to improve confinement and performance. Time-resolved radiated power profiles of the total plasma radiation in the mid-plane was measured using a 16-channel tangential bolometer. Results showed that confinement was appreciably affected during the runs with lithium deposition. Generally, ELM's were either reduced or eliminated for hundreds of milliseconds, and the density profiles were peaked, rather than flat as in typical H-mode plasmas. The metallic impurity profiles tended to be highly peaked as well, often accompanied by strong impurity accumulation in the center of the plasma. In the more severe cases, the volume-integrated radiated power would exceed 50% of the total input power and the estimated concentration of metals on axis (modeled using iron as the representative impurity) reached 0.2% of the electron density.

[1]Work supported by US DOE Contract DE-AC02-76CH03073.

TP8.00066 Spectroscopy of NSTX Plasmas During Lithium Wall Conditioning Experiments[1] , J. ROBINSON, S. PAUL, R. BELL, C.H. SKINNER, Princeton Plasma Physics Laboratory — During the 2007 NSTX campaign a lithium evaporation system, LiTER, was used to coat plasma facing components as part of a long term program to explore the potential for lithium to improve plasma and PFC performance. The plasma emission was recorded by vacuum ultra-violet and air wavelength spectrometers and showed significant changes with lithium conditioning. Preliminary results show that the lithium conditioning suppressed oxygen and hydrogen to deuterium ratios. However, with lithium applied, ELM-free H-mode plasmas were achieved, which developed high central radiation containing significant levels of metallic impurities. We will present data on the spectral emission of the plasma both with and without lithium evaporation and compare it to 2006 data.

[1]Work supported by US DOE Contract DE-AC02-76CH03073.

TP8.00067 XPS studies of NSTX tiles and in-situ analysis of Li exposed graphite simulating plasma-Li surface interactions.[1] , J.P. ALLAIN, S. HARILAL, M. NIETO, M.R. HENDRICKS, A. HASSANEIN, Argonne National Laboratory — Lithium has been considered a potentially viable plasma-facing surface enhancing the operational performance of fusion devices such as: TFTR and NSTX. In particular, lithium coatings are used in NSTX runs to enhance energy confinement. Questions remain on the role of lithiated surfaces and multi-material interactions at the plasma edge. Processes of interest are the erosion of lithiated graphite surfaces, diffusion of Li into graphite and D-retention of lithium-covered surfaces. These processes consist of spatial scales from a few monolayers at the vacuum/film interface to 100's nm deep. Studies are conducted in the IMPACT experimental facility. IMPACT is designed to study *in-situ* how multi-component surfaces evolve under particle irradiation. Techniques include: low-energy ion scattering spectroscopy (LEISS), direct recoil spectroscopy, X-ray photoelectron spectroscopy and in-situ erosion diagnosis. In this paper detailed LEISS and XPS studies of lithiated graphites surfaces simulating conditions in NSTX are presented.

[1]Work has been created in part under Contract No. DE-AC02-06CH11357

TP8.00068 UEDGE Simulations of the NSTX Liquid Lithium Divertor Module[1] , D.P. STOTLER, PPPL, R. MAINGI, ORNL, A.YU. PIGAROV, UCSD, M.E. RENSINK, T.D. ROGNLIEN, LLNL — The Liquid Lithium Divertor (LLD) module planned for installation in the lower divertor of NSTX will provide a nearly toroidally continuous liquid lithium surface in close proximity to the plasma. The objective of the module is to pump enough deuterium to allow full control of the plasma density thereby permitting high performance H-modes to be held in near steady state and increasing the fraction of non-inductively driven current. A series of UEDGE simulations has been carried out to aid in the determination of the optimal location, which may be inboard or outboard of the CHI insulating break, as well as the width of the LLD. UEDGE's transport coefficients and boundary conditions have been adjusted to match an existing NSTX discharge intended as a prototype of the high performance H-mode experiments planned for the LLD. The effect of the LLD has been incorporated into UEDGE as a reduction in the recycling coefficient over a section of the divertor. With the plasma flux coming of the core held fixed, the liquid lithium's particle absorption results in a reduction in the simulation's plasma density at the core boundary. The primary output of this study is then the variation of this density reduction with the major radius and width of the LLD.

[1]This work supported by US DOE contract DE-AC02-76CH03073.

TP8.00069 NSTX High-k Scattering System on NSTX: Status and Plan[1] , H.K. PARK, E. MAZZUCATO, D. SMITH, S. KAYE, Princeton University, C.W. DOMIER, N.C. LUHMANN, JR., UC at Davis, W. LEE, POSTECH — A multi-channel collective scattering system was commissioned on NSTX to investigate anomalous electron transport physics related to the electron density turbulence. NSTX plasma parameters with a large gyro-radius (ρ_i ∼1 cm) facilitate the investigation of the turbulence related physics in the high-k regime (k$_r\rho_s$ >3) which is not readily accessible in other toroidal devices. The system employs a moderate power (∼100 mW) source at ∼ 1 mm wavelength as the probe beam and has an excellent spatial and wavenumber resolution. The system consists of 5 discrete channels which primarily measure five radial wavenumbers up to k$_r$ ∼ 20 cm^{-1} which corresponds to k$_r\rho_e$ ∼0.2 and ∼0.7 for the NSTX edge and core parameters, respectively. Initial results from various operating regimes [edge and core of the quiescent OH, L/H modes of the RF and NBI heated plasmas] will be addressed in this paper. The observed high signal to noise ratio at the highest wave-number provides confidence in the future upgrade plan for even higher wavenumbers up to ∼50 cm^{-1} (k$_r\rho_e$ ∼2) employing a shorter probe beam wavelength in which the net S/N is comparable (optimum beam power and available detector sensitivity) to the present ∼1mm system. Upgrade plans for the tangential and poloidal high-k configuration that can share the same probe beam will be discussed.

[1]This work was supported by the U.S. Department of Energy under contract numbers DE-AC02-76CH03073, DE-FG03-95ER54295, and DE-FG03-99ER54531.

TP8.00070 Investigation of electron gyroscale fluctuations in NSTX plasmas , D.R. SMITH, R.E. BELL, J.C. HOSEA, S.M. KAYE, B.P. LEBLANC, E. MAZZUCATO, H.K. PARK, PPPL, W. LEE, POSTECH, C.W. DOMIER, N.C. LUHMANN, UC-Davis, F.M. LEVINTON, H. YUH, Nova Photonics — Electron gyroscale fluctuations are studied to reveal the existence and nature of electron temperature gradient (ETG) turbulence in NSTX plasmas. The role of parameters relevant to ETG turbulence, such as ∇T_e, $\hat{s}$, and T_e/T_i, are highlighted. Fluctuation spectra are obtained using a multi-channel, microwave scattering system that measures fluctuations with $k_\perp \leq 20$ cm^{-1} and $k_\perp \rho_e \leq 0.6$. The system can measure up to five distinct wavenumbers simultaneously, and the k-space resolution is $\Delta k_\perp \approx 0.7$ cm^{-1}. The probe and receiving beams are positioned nearly on the equatorial midplane and configured for tangential scattering, so measured fluctuations are primarily radial. Steerable optics can position the scattering volume throughout the outer half-plasma from the magnetic axis to the edge. In addition to fluctuation spectra, transport calculations using `TRANSP` and linear gyrokinetic calculations using `GS2` are also presented. This work is supported by the U.S. Department of Energy under Contract Nos. DE-AC02-76CH03073, DE- FG03-95ER54295, and DE-FG03-99ER54531.

TP8.00071 In-situ calibration of the high-k scattering system on NSTX , WOOCHANG LEE, Pohang University of Science and Technology, DAVID SMITH, HYEON PARK, Princeton Plasma Physics Laboratory, MOO-HYEON CHO, Pohang University of Science and Technology, CALVIN DOMIER, NEVILLE LUHMANN, University of California at Davis — The tangential collective Thomson scattering system which is capable of simultaneously measuring five wave-numbers has been extensively engaged in physics studies during the last campaign on NSTX. In-situ calibration of the scattering parameters as well as the receiver system is essential to quantify the detected scattered power. Calibration of the receiver system will be performed by a power modulation technique and standard hot-cold load method. One of the key scattering parameters of the tangential scattering system is the reduced scattering length due to the improved k-matching condition arising from the tight toroidal curvature and strong magnetic shear on NSTX. Theoretical assessment of the effect of the toroidal curvature and magnetic shear on the scattering length will be experimentally quantified using an acoustic cell which can excite waves with a known frequency, wavenumber and well defined direction of the propagation. In addition, measurement of other scattering parameters such as the wave number resolution and wave propagation direction of the heterodyne detection system will be addressed. This work was supported by the U.S. DOE Contract # DE-AC02-76CH03073, POSTECH BK-21, and NFRC.

TP8.00072 Separation of momentum diffusion and pinch using n=3 non-resonant braking perturbations on NSTX[1] , W. DAVIS, W.M. SOLOMON, S.M. KAYE, R.E. BELL, B.P. LEBLANC, J.E. MENARD, Princeton Plasma Physics Laboratory, Princeton University, Princeton NJ, S.A. SABBAGH, Dept. of Applied Physics, Columbia University, NYC, NY — Perturbative studies of momentum transport have been made on NSTX using n=3 non-resonant braking as a means of perturbing the rotation profile. The braking was applied for 50 ms during a relatively MHD-quiescent phase of the discharge, after which the evolution of the plasma rotation was measured. The non-local torque perturbation created by the n=3 error field created some distortion to the toroidal rotation profile, allowing the separation of momentum flux caused by diffusion (proportional to the gradient in the toroidal rotation) and a momentum pinch (proportional to the toroidal rotation). Preliminary analysis indicates the necessity of a momentum pinch to explain the profile evolution. The effect of off-diagonal terms in the momentum balance equation (eg grad(Ti), grad(ne)) are also considered.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00073 Beam Modulation Effects on NSTX Ion Power Balance[1] , P.W. ROSS, D.A. GATES, S. MEDLEY, S.M. KAYE, R.E. BELL, B.P. LEBLANC, D.S. DARROW, R. WHITE, G. ZIMMER, Princeton Plasma Physics Lab, W.W. HEIDBRINK, M. PODESTA, D. LIU, U.C. Irvine, H. YUH, F.M. LEVINTON, Nova Photonics, NSTX TEAM — The coupling between the beam particles and the thermal ions is poorly understood. To examine the coupling, the beam power was modulated. The fast particles were then measured using a variety of diagnostics. The neutron rate from beam-target interactions shows the expected behavior, with the signal decreasing to a new steady state value in <10 ms. The Neutral Particle Analyzer (NPA) shows a presence of fast ions at various pitch angles, but not at others. The NPA measurement is compared to other fast ion diagnostics including the Fast Ion D Alpha (FIDA) diagnostic, the Solid State Neutral Particle Analyzer (SSNPA) and the Scintillator Fast Loss Ion Probe (SFLIP) diagnostic. Comparison is also made between measured NPA signals and TRANSP calculations. The ion and electron temperature were also measured and compared before and after the start of the modulation, and conclusions are drawn about the coupling between the beam and the plasma.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00074 Fast electron temperature, MHD and transport measurements on NSTX using a multi-energy SXR array , L.F. DELGADO-APARICIO[1], D. STUTMAN, K. TRITZ, M. FINKENTHAL, The Johns Hopkins University, R. BELL, J. HOSEA, S. KAYE, B. LEBLANC, Princeton Plasma Physics Laboratory, S. SABBAGH, Columbia University — A compact multi-energy soft X-ray array has been developed for fast ($\leq$0.1 ms) time and space-resolved electron temperature, MHD and transport measurements on the National Spherical Torus Experiment (NSTX). The electron temperature is obtained by modeling the slope of the continuum radiation from ratios of the Abel inverted radial emissivity profiles in three energy ranges [1]. The applicability of this diagnostic technique to radio frequency electron heating and current drive experiments, perturbative electron and impurity transport studies, as well as an analysis of the impact of several types of MHD activity such as NTMs, RWMs, ELMs and Fishbones will be discussed. This work supported by U.S. DoE Contract No. DE-AC02-76CH03073 DoE and grant No. DE-FG02-99ER5452 at The Johns Hopkins University.
[1] L. F. Delgado-Aparicio, et al., Plasma Phys. Controlled Fusion, **49**, 1245 (2007).

[1]delgapa@pha.jhu.edu

TP8.00075 Time-dependent measurements of the B, C, N, and O Lyman-α emission[1] , P. BEIERSDORFER, M.-F. GU, LLNL, M. BITTER, K.W. HILL, R. KAITA, H. KUGEL, L. ROQUEMORE, PPPL, J.K. LEPSON, UC Berkeley — The X-ray and Extreme Ultraviolet Spectrometer (XEUS) has been used to monitor the line emission from various impurity ions on NSTX, in particular the K-shell emission of heliumlike and hydrogenlike B, C, N, and O. While C VI typically dominates the spectrum, unusually strong emission from N VII has been observed in multiple disharges during the past run campaign. In this case, the nitrogen concentration can exceed that of carbon by an order of magnitude. Time-dependent measurements show that the nitrogen concentration builds up over the course of the discharge and coincides with a build up of boron. In a few cases we observed several unknown lines. These are clearly lines from heavy impurities, possibly molybdenum. Some of these lines can be explained by the emission from Ti XIII.

[1]This work was performed under the auspices of the U.S. DOE by UC-LLNL under contract W-7405-Eng-48 and by PPPL under contract DE-AC02-76CHO3073.

TP8.00076 The Motional Stark Effect Diagnostic on NSTX[1] , FRED LEVINTON, HOWARD YUH, Nova Photonics, Inc. — This work describes the implementation and recent results from the MSE-CIF diagnostic on NSTX. Due to the low magnetic field on NSTX the MSE diagnostic requires a new approach for the viewing optics and spectral filter. This has been accomplished with a novel optical design that reduces the geometric Doppler broadening, and a high throughput, high resolution spectral filter to optimize signal-to-noise. This MSE diagnostic presently has 16 of a possible 19 sightlines operating, providing measurements of the magnetic field line pitch from the plasma center to near the outboard edge of the plasma. The system operates well at low magnetic field, $\geq$0.3 T, using collisionaly induced fluorescence (CIF) from a deuterium heating beam operating at about $\sim$90 keV. MSE data has been obtained in several regimes, including L-mode, H-mode, and reversed shear. The measurements reveal the development of both monotonic and reversed shear q-profiles depending on the discharge evolution. The presence of MHD is found to have a significant effect on the profile evolution and will be discussed.

[1]This work supported by U.S. DOE contracts DE-FG02-99ER54520 and DE-AC02-76CH03073.

TP8.00077 Millimeter-wave measurements of edge electron density profile and fluctuations during NSTX H-mode discharges[1] , S. KUBOTA, W.A. PEEBLES, N.A. CROCKER, X.V. NGUYEN, R.J. MAQUEDA, Nova Photonics, R. MAINGI, C.E. BUSH, ORNL, G.J. KRAMER, PPPL, THE NSTX TEAM — The fast evolution of the density profile and the associated changes in turbulence are measured near the plasma edge in NSTX H-mode discharges using millimeter-wave reflectometry. FMCW reflectometry (13-50 GHz) provides fast profile measurements with 20 us resolution, while multiplexed fixed-frequency systems (30, 35, 42, 44.5, 50, 65 GHz) monitor fluctuations at various cutoff densities. A new correlation reflectometer (29-40 GHz) is used to measure the poloidal propagation of turbulence. The bulk poloidal velocity can be inferred from these measurements while the propagation of individual turbulence structures is also visible. In addition to the L-H transition, profile and turbulence characteristics are monitored for the various ELM types (Type I, Type III and Type V) present in NSTX.

[1]Supported by U.S. DoE Grant DE-FG03-99-ER54527.

TP8.00078 NSTX H-mode measurement in conjunction with gyrocenter shift via FIReTIP system[1] , M. JOHNSON, C.W. DOMIER, K.C. LEE, N.C. LUHMANN, JR., University of California Davis, P.W. ROSS, R. BELL, H. PARK, Princeton Plasma Physics Laboratory — The Far Infrared Tangential Interferometer/Polarimeter (FIReTIP) which spans the entire plasma is used to measure electron density fluctuations during the low confinement mode (L-mode) to high confinement mode (H-mode) transition on the National Spherical Tokamak Experiment (NSTX). The measured neutral density distribution and the radial electric field evolution are compared to the calculations based on the gyrocenter shift [K. C. Lee, *Phys. Plasmas***13**, 062505 (2006)].The statistical analysis of electron density fluctuations measured by the FIReTIP system including data from a newly installed additional channel will be reported. Also, the role of the neutral density gradient on the L to H transition associated with the radial electric field formation and turbulence suppression will be discussed.

[1]This work is supported by U.S. Department of Energy Grants DE-FG03-99ER54518 and DE-AC02-76CH03073.

TP8.00079 Bandwidth Upgrade for the NSTX FIReTIP System[1] , W-C. TSAI, C.W. DOMIER, K.C. LEE, N.C. LUHMANN, JR., University of California at Davis, H.K. PARK, Princeton Plasma Physics Laboratory — The multichannel Far Infrared Tangential Interferometer/Polarimeter (FIReTIP) system, installed on the National Spherical Tokamak Experiment (NSTX) which has a great potential to be used as a monitoring system for the density fluctuations spanning from micro-turbulence to coherent MHD activities, is currently limited to a 250 kHz video bandwidth. New electronics under development at UC Davis will extend this to approximately 4 MHz in order to access the high frequency density fluctuation spectra and compressional Alfvén eigenmodes (CAE) modes driven by supra-Alfvénic neutral beam ions on NSTX. Such instabilities are expected to be important for the performance of the ITER burning plasma, where neutral beam and fusion alpha ions are also supra-Alfvénic. Additional electronics will allow the study of high harmonic fast wave (HHFW) induced 30 MHz density fluctuations superimposed on the FIReTIP signals. Technical details regarding the FIReTIP upgrade will be presented.

[1]Work supported by U.S. DoE Grants DE-FG02-99ER54518 and DE-AC02-76CH03073.

TP8.00080 Control of asymmetric magnetic perturbation in tokamaks by computation of ideal perturbed equilibria[1]

JONG-KYU PARK, JONATHAN MENARD, Princeton Plasma Physics Laboratory, ALLEN BOOZER, Columbia University, MICHAEL SCHAFFER, General Atomics — It is well known that tokamak plasmas are highly sensitive to a small breaking of axisymmetry by external magnetic perturbations. The newly developed Ideal Perturbed Equilibrium Code (IPEC) computes an ideally perturbed equilibrium by the perturbations, thereby yielding the three-dimensional features of the perturbed plasma in high resolution. The application of the code to observations of locked modes in NSTX and DIII-D resolved paradoxical results and revealed the most sensitive mode of external perturbations, whose reduction is most important for the control of field error problems in tokamaks. IPEC has numerous applications, such as error field mitigation in ITER or the plasma response to ELM control coils. IPEC can be extended to compute the perturbed equilibria in the presence of plasma viscous forces due to the toroidal asymmetries in the magnetic field strength and can be compared with measured plasma responses in NSTX.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00081 Nonlinear Study of Error Field Effects in NSTX

J.A. BRESLAU, J.K. PARK, A.H. BOOZER, W. PARK, J.E. MENARD, Princeton Plasma Physics Laboratory — RWM stabilization by plasma rotation in NSTX is impeded by the presence of a time-dependent non-axisymmetric component to the toroidal field [1]. Confinement is improved by active correction of this error field; its exact cause is still under investigation. A numerical study of the effects of the error field on magnetic island formation was conducted with ideal linear codes [2], providing estimates of the island widths based on the amplitudes of the singular current sheets that result from the perturbation. We extend these results by conducting nonlinear, non-ideal studies of these effects using the M3D code [3]. The nonlinear correction to the linear response to a pure m=2, n=1 perturbation is shown, followed by investigations of the effects of toroidal rotation and of mode locking and consequent rotation damping.

[1] J.E. Menard, et al., submitted to Nucl. Fus., 2007.
[2] J.K. Park, poster presented at Sherwood Fusion Theory Conference, Annapolis, MD, April 2007.
[3] W. Park, et al., Phys. Plasmas 6, 1796 (1999).

TP8.00082 MHD Induced Neutral Beam Ion Loss from NSTX[1]

DOUGLASS DARROW, ERIC FREDRICKSON, NIKOLAI GORELENKOV, LANE ROQUEMORE, PPPL, NEAL CROCKER, UCLA, KOUJI SHINOHARA, JAEA — Bursts of MHD activity at ~60 kHz occur commonly in NSTX plasmas, particularly at high beta, and are accompanied by neutral beam ion loss over a range in pitch angles. The pitch angle and energy distributions of these losses have been measured with a scintillator type loss probe viewed by a high speed video camera. The data from one representative burst that causes a 13% reduction in the neutron rate has been studied thoroughly and has several interesting features. At first, the mode has a purely n=1 character, sweeping downward in frequency. There is no change to the underlying prompt loss signal during this interval, indicating there is no phase space transport of fast (80 keV D) ions into the loss cone from the frequency sweeping. Later, a concurrent n=2 mode arises, followed quickly by a concurrent n=3 mode. When multiple modes are present, loss is seen over a wide range of pitch angles, suggesting stochastization of the beam ion orbits. There is no evidence of any sweeping in pitch angle of the loss in either phase of the burst, at least not on the 100 us time scale.

[1]This work performed under US DoE contract DE-AC02-76-CH03073.

TP8.00083 Neutral Particle Analyzer Vertically Scanning Measurements of MHD-induced Fast Ion Redistribution or Loss in NSTX[1]

S.S. MEDLEY, R. ANDRE, R.E. BELL, D. DARROW, Princeton University, C.W. DOMIER, UC Davis, E. FREDRICKSON, N. GORELENKOV, S. KAYE, B. LEBLANC, K.C. LEE, Princeton University, F. LEVINTON, Nova Photonics, N.C. LUHMANN, JR., UC Davis, D. LIU, UC Irvine, J. MENARD, H. PARK, D. STUTMAN, L. ROQUEMORE, Princeton University, K. TRITZ, Johns Hopkins University, H. YUH, Nova Photonics — Observations of MHD-induced redistribution or loss of energetic ions measured using the vertically scanning capability of the Neutral Particle Analyzer diagnostic on the National Spherical Torus Experiment (NSTX) are presented along with TRANSP analysis. Although redistribution or loss of energetic ions due to low-f $\sim$ 10 kHz continuous kink-type MHD was reported previously [1,2], here the primary goal is to study redistribution or loss due to continuous Alfvénic (f $\sim 20 - 150$ kHz) modes. Initial indications are that the former drive energetic ion loss whereas the continuous Alfvénic modes at most only cause redistribution and the energetic ions remain confined.

[1] S. S. Medley, *et al.*, Nucl. Fusion **44**, (2004) 1158
[2] J. E. Menard, *et al.*, Phys. Rev. Lett. **97**, (2006) 095022

[1]Research supported by U.S. DOE contract DE-AC02-76-CH03073.

TP8.00084 Effect of halo neutrals on neutral particle measurements[1]

D. LIU, W.W. HEIDBRINK, UC Irvine, S.S. MEDLEY, A.L. ROQUEMORE, PPPL, R.J. AKERS, UKAEA — The Neutral Particle Analyzer (NPA) diagnostics including the E||B type NPA and solid state NPA (ssNPA) array on the National Spherical Torus Experiment (NSTX) measure neutral production in charge exchange reactions between energetic ions and beam primary and halo neutrals. A Monte Carlo simulation code is developed to analyze the effect of primary neutrals and halo neutrals to the NPA flux temporal evolution and energy spectrum. The code is validated by comparing with the TRANSP-simulated NPA signals and an analytical halo diffusion model. The simulation results show that the density of halo neutrals around the beam footprint is comparable to that of primary neutrals. Charge exchange with halo neutrals contribute significantly to the neutral flux measured by NPA diagnostics for typical NSTX conditions. Effect of halo neutrals in quiet plasmas and discharges with beam modulation and vertical NPA scans will be presented.

[1]This work was supported by US DOE Grant DE-FG03-02ER54681.

TP8.00085 Excitation of Beta-induced Alfven-acoustic eigenmodes and q-profile MHD spectroscopy in NSTX.[1]

NIKOLAI GORELENKOV, E.D. FREDRICKSON, PPPL, Princeton University, H.L. BERK, IFS, Austin, TX, NSTX TEAM — We report on observations and interpretations of a new class of global MHD eigenmode solutions arising in gaps in the low frequency Alfvén -acoustic continuum below the geodesic acoustic mode (GAM) frequency. These modes have been just reported [N. N. Gorelenkov *et.al.*, Phys. Letters A, doi:10.1016/j.physleta.2007.05.113 (2007)] are the result of coupling of the Alfvén and acoustic continua due to geodesic curvature. We show good quantitative comparison of the theory predictions with recent NSTX experiments on the observations of these modes, referred to as Beta-induced Alfvén - Acoustic Eigenmodes (BAAE). They exist near the extrema points of the Alfvén - acoustic continuum and can sweep up in frequency from zero value in the plasma frame as q-profile relaxes. We show that the measurements of BAAE frequency can be used to infer q_{min} in both reversed and monotonic q-profile plasmas. In NSTX experiments we see a correlation of the MSE measured q-profile evolution and BAAE instabilities. TRANSP code is used to understand q-profile evolution by comparing it to classical predictions.

[1]Supported by DOE contracts No. DE-AC02-76CH03073 and DE-FG03-96ER-54346.

TP8.00086 Nonlinear simulations of NBI driven GAE modes in NSTX[1]

, E.V. BELOVA, N.N. GORELENKOV, PPPL — Hybrid 3D code HYM is used to investigate beam ion effects on MHD modes in a NSTX, aiming at simulations of NSTX shots where chirping frequency GAE/CAE modes have been observed. Thermal plasma is modeled using the MHD equations, and full-orbit delta-f kinetic description is used for the beam ions. Simulations show that for large neutral beam injection velocities and strong anisotropy in the pitch-angle distribution, many Alfven modes are excited. Unstable GAEs modes for $2 < n < 7$ and weakly unstable CAE for $n > 7$ are observed. Scaling of the growth rate of GAE mode with beam ion density is stronger than linear due to significant modification of plasma equilibrium profiles. Profile modification is due to self-consistent beam ion effects, and it has indirect effect on the stability. It was demonstrated that phase velocity of the unstable GAE mode has opposite sign compared to the beam injection velocity, and the resonant particles satisfy Doppler-shifted cyclotron resonant conditions. Dependence of the growth rate on dissipation parameters is studied. Nonlinear simulations show that the GAE instability saturates at low amplitude.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00087 Development of a Fast-Ion D-Alpha diagnostic for NSTX[1]

, MARIO PODESTA', W.W. HEIDBRINK, UC Irvine, CA 92697, R.E. BELL, W. SOLOMON, PPPL, Princeton, NJ 08543, V. SOUKHANOVSKII, LLNL, Livermore, CA 94550 — A Fast-Ion D-Alpha diagnostic based on active charge exchange recombination spectroscopy is being developed for NSTX. The first results from the 2007 run, obtained with a prototype setup, indicate that fast ion signals have been successfully detected. The signals show a clear time correlation with the neutron emission from beam-plasma reactions. During modulation of the injected neutral beam power, variations on the fast ion slowing down time-scale are observed. The signal amplitude from different spectral regions scales accordingly with the fast ion D_α spectrum. For the 2008 run, sixteen channels will cover the outboard poloidal cross-section with a resolution in space, time and energy of 5cm, 10ms and 10keV. In addition, three dedicated channels will monitor the signal from suprathermal ions on time-scales ~10us at different radii. Each channel includes two views inside the plasma, intercepting/missing the neutral beam for a direct subtraction of the background signal not associated with fast ions.

[1]Work supported by US DOE grant DE-FG02-06ER54867 and contract DE-AC02-76CH03073

TP8.00088 Identification and Study of MHD modes on NSTX using Soft X-ray Images[1]

, C.E. BUSH, Oak Ridge National Laboratory, B.C. STRATTON, J. ROBINSON, L.E. ZAKHAROV, E.D. FREDRICKSON, Princeton Plasma Physics Laboratory, D. STUTMAN, K. TRITZ, Johns Hopkins University — Theory and experiments indicate that MHD phenomena can cause significant fast particle losses which in turn lead to heating power loss and elevated wall power loading in present experiments and possibly future burning plasma devices. It is important for STs, ITER, and ITPA database scaling to understand the dominant MHD modes and their effects on fast particles. We have studied the spatial structure and time behavior of the MHD in NSTX using a unique fast soft x-ray imaging camera with a wide-angle (pinhole) tangential view of nearly the entire plasma minor cross section. The camera provides a 64x64 pixel image, on a CCD chip, of light resulting from conversion of soft x-rays incident on a phosphor to the visible. We have acquired plasma images at frame rates of 1-500 kHz (300 frames/shot), and have observed a variety of MHD phenomena: internal reconnection events, disruptions, sawteeth, fishbones, tearing modes, and ELMs. This is important to ITER due to fast particle (α's,etc.) losses. Modes with frequency > 90 kHz have been observed.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073 and DE-AC05-00OR22725.

TP8.00089 Numerical Investigations of Instability-Induced Current Redistribution in a Spherical-Torus Plasma

, PETER NORGAARD, Princeton University, JONATHAN MENARD, ROSCOE WHITE, Princeton Plasma Physics Laboratory, YURIY YAKOVENKO, National Academy of Sciences of Ukraine, DOUGLAS MCCUNE, Princeton Plasma Physics Laboratory, CLARENCE ROWLEY, Princeton University — Recent experimental observations suggest that interchange-type instabilities may play an important role in redistribution of the neutral beam injected current in the National Spherical Torus Experiment (NSTX). In our present work, the guiding center orbits of various test particles are integrated in the presence of a prescribed magnetic perturbation using a modified version of the ORBIT code. The perturbation modes are derived from NSTX diagnostic data during periods where instability-induced redistribution is observed experimentally. These results show the possibility of enhanced transport for certain regions of phase space. Simulations are also presented which show the time evolution of the neutral beam injected ion distribution, where the initial profile is obtained using a newly developed component for NUBEAM, part of the TRANSP software package. Ultimately, we hope to develop a self-consistent model for instability-induced current redistribution, including possible self-regulation between the fast-ion current and the core MHD instabilities.

TP8.00090 SOL width scale lengths in NSTX

, JOON-WOOK AHN, JOSE BOEDO, UCSD, RAJESH MAINGI, ORNL, VLAD SOUKHANOVSKII, LLNL, HENRY KUGEL, LANE ROQUEMORE, PPPL — The SOL T_e and n_e profiles have been investigated with a mid-plane fast reciprocating probe in NSTX. The SOL plasma consists of two regions; a region close to the LCFS where a steep gradient of the profile is observed (*ie* near SOL region) and a region further away from the LCFS where a flatter profile is observed (*ie* far SOL region). It was observed that the near SOL T_e and n_e decay lengths (λ_{Te} and λ_{ne}) became significantly longer in L-mode compared to H-mode (a factor of ~2 increase in λ_{Te} and ~3 increase in λ_{ne}). It was found that both λ_{Te} and λ_{ne} in the near SOL decrease with increasing plasma current (I_p) in H-mode (from λ_{Te} ~3cm to ~1cm and λ_{ne} ~2cm to ~1cm with I_p variation from 0.8MA to 1MA). Near SOL λ_{Te} and λ_{ne} in L-mode increased (λ_{Te} ~0.7cm to ~1.1cm and λ_{ne} ~1.5cm to ~2.1cm) with increasing line averaged density (from 2.7 to 3.1x10^{13}cm^{-3}) and decreased (λ_{Te} ~1.7cm to 0.4cm and λ_{ne} ~1.3cm to 0.5cm) with increasing input power (P_{NBI} ~1MW to 4MW). A comparison with Thomson Scattering (TS) data shows a reasonably good match for T_e and n_e profiles. *This work was supported by U.S. DOE contract # DE-FG02-03ER54731 and DE-AC02-76CH03073*.

TP8.00091 Electrode Biasing Experiment for Local SOL Control In NSTX[1]

, LANE ROQUEMORE, STEWART ZWEBEN, PPPL, CHARLES BUSH, ORNL, RICARDO MAQUEDA, Nova Photonics, ROBERT MARSALA, YEVGENY RAITSES, PPPL, RONALD COHEN, DMITRI RYUTOV, MAXIM UMANSKY, LLNL — A set of small electrodes was installed in NSTX to test a proposal to control the width of the scrape-off layer (SOL) by biasing the electrodes to create a strong local poloidal electric field [1,2]. The electrodes in NSTX were ~ 3 cm outside the separatrix near the outer midplane, and were biased in the range -95 V to +50 V with a poloidal separation of ~ 1 cm. The effect of this local biasing was measured with Langmuir probes between the electrodes, and by the NSTX gas puff imaging (GPI) diagnostic located ~1 m away along the magnetic fields lines intersecting the electrodes. Changes in the local density and potential were seen by the probes in some cases, but little change was seen in the D_α profile or the turbulent motions as seen by the GPI diagnostic. Analysis of the perpendicular and parallel penetration lengths of the biasing potential and a comparison with the MAST experiments will be presented.

[1] D. Ryutov et al, Plasma Phys. Cont. Fusion 43 (2001) 1399
[2] R.H. Cohen et al, Plasma Phys. Cont. Fusion 49 (2007) 1

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00092 Structure and evolution of ELMs in the edge and SOL of NSTX[1] , R.J. MAQUEDA, Nova Photonics, R. MAINGI, C.E. BUSH, ORNL, K. TRITZ, Johns Hopkins Univ., J.-W. AHN, J.A. BOEDO, UCSD, S. KUBOTA, UCLA, E. FREDRICKSON, S.J. ZWEBEN, PPPL, NSTX TEAM — Edge Localized Modes (ELMs) are routinely seen during H-mode operation in NSTX. These ELMs have been characterized as large-sized Type I, medium-sized Type III, and small Type V ELMs. Recently, an experiment was dedicated to characterize the structure and evolution of these 3 ELM Types in NSTX utilizing multiple diagnostics. These diagnostics include: fast-framing digital cameras, soft X-ray arrays, edge probes (both tile-embedded and reciprocating), reflectometers and Mirnov arrays. In general, the ELM evolves from a perturbation of the edge topology that quickly develops (<30 μs) into strong filamentation that propagates both radially and poloidally/toroidally in the SOL. This ELM filamentation is then followed by an increased level of edge turbulence (and blobs) resembling, momentarily, that observed during L-mode phases. This later blob filamentation is clearly distinct from the initial ELM structures. The characteristics and differences observed in all 3 ELM Types will be presented.

[1]Work supported by DoE grants DE-FG02-04ER54520, DE-AC02-76CH03073, and DE-AC05-00OR22725.

TP8.00093 Study of statistical properties of edge turbulence in NSTX with the GPI diagnostic , MATTEO AGOSTINI, Consorzio RFX, STEWART ZWEBEN, PPPL, ROBERTO CAVAZZANA, PAOLO SCARIN, GIANLUIGI SERIANNI, Consorzio RFX, RICARDO MAQUEDA, Nova Photonics, DAREN STOTLER, PPPL — The Gas Puff Imaging (GPI) diagnostic is used to study the edge turbulence of the NSTX spherical tokamak. The statistical properties of the edge fluctuations are characterized as a function of the radial position, using the Continuous Wavelet Transform, showing their lack of self-similarity. Bursts are identified in the signals; the correlation between the electron pressure radial profile and the percentage of bursts is shown. The difference between L and H mode is studied, correlating it with the amount of coherent structures in the edge plasma. In the H-mode discharges the linear density of structures decreases drastically compared to the L-mode case; it is also shown that such observation cannot be accounted for by the difference in the poloidal propagation velocity measured near the separatrix. The spectral properties are studied by measuring the power spectrum as a function of the poloidal wavenumber k: a difference between the two confinement regimes is found.

TP8.00094 Reduced simulations of boundary turbulence in NSTX[1] , D.A. RUSSELL, J.R. MYRA, D.A. D'IPPOLITO, Lodestar Research Corporation, R. MAQUEDA, Nova Photonics, V. SOUKHANOVSKII, LLNL, S.J. ZWEBEN, PPPL, AND THE NSTX TEAM — We solve a reduced set of equations numerically for the evolution of vorticity, density, temperature and zonal fluid momentum, in the two dimensions orthogonal to the magnetic field, in the edge and SOL of a tokamak. In the simulation plane, the edge region supports the electron drift wave instability, while sheath losses and the grad-Te instability are isolated in the SOL. Curvature- and grad-B-driven charge separation is included everywhere, enabling blob transport of density, temperature and vorticity (charge) from the edge into the SOL. Generic features of boundary turbulence seen in NSTX and other experiments are reproduced by the simulations, including skewed PDFs, power law frequency spectra, skewness vs. distance from the separatrix, and qualitative features seen with Gas Puff Imaging. We will also report on our modeling of divertor disconnection/detachment experiments in NSTX for which blob speed-up and SOL-broadening are predicted theoretically.

[1]Supported by the USDOE under grants DE-FG02-02ER54678 and DE-FG02-97ER54392 and under contracts DE-AC02-76CH03073 and W-7405-Eng-48.

TP8.00095 Modeling of Blob Formation in NSTX Edge Turbulence[1] , T. STOLTZFUS-DUECK, J.A. KROMMES, S.J. ZWEBEN, Princeton U. — In tokamak edge turbulence, predominantly electrostatic cross-field nonlinearities are balanced with wavelike parallel coupling that is often electromagnetic. Magnetic field fluctuations affect both the parallel coupling and dissipative properties of the turbulence at perpendicular scales larger than the skin depth. The resulting mathematical structure is discussed as are approaches to, and limitations of, 2D approximations. A specific reduced 2D fluid model appropriate for modeling of "blob" formation in the electromagnetic NSTX edge is derived both semi-heuristically and from a systematic projection method. Initial numerical solutions will be presented, and their frequency and wave-number spectra will be compared with experimental results from the gas-puff imaging diagnostic on NSTX.

[1] This work is supported in part by U.S. Dept. of Energy Contract #DE-AC02-76-CHO-3073 and based upon work supported under a National Science Foundation Graduate Research Fellowship.

TP8.00096 Spectroscopic T_e and n_e measurements in a recombining divertor region and in MARFEs in NSTX using D I and He II high-n series line emission. , V.A. SOUKHANOVSKII, LLNL, R.E. BELL, R. KAITA, A.L. ROQUEMORE, PPPL, R. MAQUEDA, Nova Photonics — Spatially resolved measurements of Balmer and Paschen series D I line emission, and for the first time, Pfund and Humphreys series He II emission, have been performed in the divertor and MARFE regions in 2-6 MW NBI-heated deuterium and helium plasmas in NSTX. We analyze relative intensities and Stark broadening of the ultraviolet, visible and near infrared lines corresponding to the $2-n$, $3-m$ transitions (D I) and $5-k$, and $6-l$ (He II) with upper principal quantum numbers n =7-13, m =5-12, k =10-19, and l =12-16. Temperatures in the range 0.5-1.5 eV and densities in the range $(0.5-5)\times 10^{20}$ m^{-3} are inferred using collisional-radiative modeling and published tabulated line shape calculations, confirming the important role of the three-body recombination process as an ion momentum loss mechanism in the detachment and radiative instability development. The diagnostic potential of the spectroscopic techniques for a divertor of a burning plasma device will be discussed. This work is supported by U.S. DoE under contracts W-7405-ENG-48 and DE-AC02-76CH03073.

TP8.00097 Recent observations of dust particle behavior in the NSTX[1] , W.U. BOEGLIN, FIU, A.L. ROQUEMORE, C.H. SKINNER, PPPL, R. MAQUEDA, Nova Photonics, N. NISHINO, Hiroshima University, A.YU. PIGAROV, R.D. SMIRNOV, S.I. KRASHENINNIKOV, UCSD — Highly mobile incandescent dust particles are routinely observed on NSTX using fast cameras operating in the visible region. Dust particle trajectories in both the main chamber as well as in the divertor region of NSTX have been derived using two fast cameras, each tracking the same particle from two different locations. A 3-D tracking code has been developed that uses the two-camera system to locate particles to within an accuracy of a few millimeters by correlating the position with monuments on the vessel walls. Velocities between 10-200 m/s have been measured in each region. We will also present the results of simulations on the dynamics of measured dust particles using the 3-D dust transport code (DUSTT). In matching experimental particle trajectories using DUSTT we adjusted the initial particle parameters (radius, birth point, etc) and used a plasma background calculated with UEDGE. Abnormal trajectories containing abrupt changes in direction and velocity will also be discussed.

[1]Supported by DoE contract No. DE-AC02-76CH03073.

TP8.00098 Upgrade of the NSTX Plasma Control System* , D. MUELLER, D. GATES, M. ISAACS, J. LAWSON, C. LUDESCHER-FURTH, R. MARSALA, D. MATROVITO, P. SICHTA, Princeton University — The plasma control system for the National Spherical Torus Experiment (NSTX) has been upgraded to replace the obsolete SKY computer system. The three main improvements with the new system are 1) higher computer speed, 2) lower latency and 3) a recordable absolute time during the discharge. The eight 333 MHz G4 processors in the Sky system were replaced with four dual core AMD Opteron 880 2.4 GHz processors. This provides approximately 7 times the speed for computationally intensive parts of the control system. The data acquisition and control were previously shared between VME and front panel dataport (FPDP) hardware. Two PCI FPDP cards, one each for data input and output made elimination of the VME hardware possible. Presently, the input data is read directly from the FIFO, this results in a loss of speed compared to the full potential of the vmetro FPDP DPIO2 boards using DMA, nevertheless, the present latency is about 2/3 that of the old system. In the old system, time was computed relative to a start trigger and was calculated based on input data frequency and the real-time cpu clock frequency. A digital input and time stamp module (DITS) was developed to provide a 48 bit absolute timestamp for each input data sample. *This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

TP8.00099 Model-Based Shape Control Design for the National Spherical Torus Experiment (NSTX)[1] , MAJED ALSARHEED, EUGENIO SCHUSTER, Lehigh University, DAVID GATES, Princeton Plasma Physics Laboratory, JIM LEUER, MICHAEL WALKER, DAVID HUMPHREYS, General Atomics — Plasma shape and position control is a challenging problem due to the difficulties associated with real-time shape identification, plasma parameters measurement, and control method selection. The recent implementation of the real-time equilibrium reconstruction code rtEFIT on NSTX allows plasma shaping by controlling the magnetic flux at the plasma boundary. A non-model-based shape controller that exploits this capability has been recently proposed [1]. We describe current efforts to develop a robust model-based multi-input-multi-output (MIMO) controller to provide real-time shaping and position control in the presence of disturbances and uncertainties in the plasma parameters. The control design is based on linear plasma response models derived from fundamental physics assumptions. Computer simulation results illustrate the performance of the model-based shape control method. [1] D.A. Gates, et al., Nucl. Fusion **46** (2006) 17–23.

[1]Supported by the Pennsylvania Infrastructure Technology Alliance (PITA), the NSF CAREER award program (ECCS-0645086), and the US DOE (DE-FG03-99ER54522, DE-AC02-76CH03073).

TP8.00100 Supersonic gas jet fueling efficiency studies in NSTX.* , D.P. LUNDBERG, Princeton U., V.A. SOUKHANOVSKII, LLNL, M.G. BELL, R.E. BELL, R. KAITA, H.W. KUGEL, B.P. LEBLANC, J.E. MENARD, A.L. ROQUEMORE, D.P. STOTLER, PPPL, R. MAINGI, ORNL, R. RAMAN, U. Washington — Electron and carbon inventory analysis is used to infer the fueling efficiency (FE) of a pulsed high-pressure supersonic D_2 jet, produced by a low field side supersonic gas injector (GI) at a flow rate $3-9\times10^{21}$ s^{-1} at distance 5-15 cm from the plasma. In ohmic and 2-6 MW NBI-heated L- and H-mode plasmas, the FE of the Mach 4 jet is found to be in the range 0.1-0.4, higher than FE of a conventional GI. During supersonic GI pulses, the pedestal density increases by 5-40 % suggesting that particles are deposited mainly in the pedestal region. A "single particle" model of lower-end pressure supersonic GI fueling is developed using the DEGAS 2 neutral transport code. Details of high-pressure jet interaction with background plasma are not included in the model. The modeling suggests that adding a directed velocity does not guarantee a FE improvement. While the supersonic GI does focus the molecules towards the core, there is a reduction in the number of dissociation product atoms that provide much of the transport for the conventional puff, resulting in comparable FE's of a supersonic and a conventional GI's. *Supported by U.S. DOE under Contracts W-7405-Eng-48 and DE-AC02-76CH03073.

TP8.00101 HHFW Heating and Current Drive Progress on NSTX[1] , P.M. RYAN, E.F. JAEGER, J.B. WILGEN, ORNL, J.C. HOSEA, J.R. WILSON, R.E. BELL, S. BERNABEI, B.P. LEBLANC, C.K. PHILLIPS, PPPL, L. DELGADO-APARICIO, K. TRITZ, John Hopkins University, S. SABBAGH, Columbia University, H. YUH, Nova Photonics — Operation of NSTX at $B_T(0)$ = 0.55 T has increased the core power deposition and heating efficiency of the 30 MHz High Harmonic Fast Waves (HHFW) compared to previous $B_T(0) \leq 0.45$ T operation, particularly when launching longer parallel wavelengths. This improvement is attributed in part to moving the onset density at which the fast waves begin to propagate into the plasma to a point further from the wall [1]. At this field strength the HHFW power deposition at $k_{||}$ = 7 m^{-1} is comparable to that of $k_{||}$ = 14 m^{-1}, and core heating at $k_{||}$ = 3 m^{-1} is now seen, albeit at lower efficiency. Comparisons with power deposition from full-wave models (AORSA) will be made and MSE measurements of driven current will be presented.
[1] see Invited Talk by J. Hosea, this conference.

[1]This research used resources of the National Center for Computational Sciences at Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725

TP8.00102 Numerical Modeling of High Harmonic Fast Wave Heating on NSTX[1] , C.K. PHILLIPS, J.C. HOSEA, R.E. BELL, B.P. LEBLANC, J.B. PARKER[2], E.J. VALEO, J.R. WILSON, NSTX Team, PPPL, P.M. RYAN, E.F. JAEGER, J.B. WILGEN, ORNL, S.A. SABBAGH, Columbia University, P.T. BONOLI, J.C. WRIGHT, PSFC-MIT, R.W. HARVEY, CompX, R.J. DUMONT, CEA-Cadarache — High harmonic fast wave (HHFW) heating and current drive processes, at frequencies up to 15 times the fundamental deuterium cyclotron frequency, are being studied on NSTX. Recent experiments indicate that the core heating efficiency depends strongly on the antenna phasing and plasma conditions [1]. The wave propagation and absorption characteristics for select NSTX discharges will be analyzed using a variety of rf modeling codes, including both ray tracing and full wave models. Both core power deposition profiles and rf power flow in the edge regions will be considered. The possibility of off-axis mode conversion of the HHFW to shorter wavelength modes and the subsequent impact on power deposition will be explored.
[1] See invited talk by J. C. Hosea this meeting for details

[1]Work supported by USDOE DE-AC02-76CH03073.
[2]Cornell University

TP8.00103 Recent EBW Emission Results and Plans for a 350 kW, 28 GHz EC/EBW Heating System on NSTX[1] , G. TAYLOR, S.J. DIEM, R.A. ELLIS, E. FREDD, N. GREENOUGH, J.C. HOSEA, Princeton U., T.S. BIGELOW, J.B. CAUGHMAN, D.A. RASMUSSEN, P.M. RYAN, J.B. WILGEN, ORNL, R.W. HARVEY, A.P. SMIRNOV, N.M. ERSHOV, CompX, J. PREINHAELTER, J. URBAN, Czech Inst. of Plasma Phys., A.K. RAM, MIT — Electron cyclotron heating (ECH) and electron Bernstein wave EBW heating (EBWH) can assist plasma startup on the low aspect ratio NSTX device and provide sufficient electron heating to allow effective high harmonic fast wave (HHFW) coupling during current ramp up. EBW current drive (EBWCD) can also provide off-axis current to stabilize solenoid-free NSTX plasmas at β >20%. Efficient coupling of externally launched electromagnetic waves to EBWs is required for EBWH and EBWCD. The prospect for EBWH and EBWCD is supported by EBW emission studies on NSTX that show efficient EBW coupling for some edge conditions. A 350 kW 28 GHz ECH/EBWH system is being installed on NSTX to support solenoid-free startup, HHFW current ramp up and initial EBW coupling and heating studies. This system will provide on-axis second harmonic ECH/EBWH in NSTX. Fundamental on-axis heating may also be possible by operating the gyrotron at 15.3 GHz.

[1]Work supported by USDOE DE-AC02-76CH03073

TP8.00104 Investigation of collisional EBW damping and its importance to EBW emission from NSTX[1] , JAKUB URBAN, JOSEF PREINHAELTER, EURATOM/IPP.CR Association, STEPHANIE J. DIEM, GARY TAYLOR, PPPL, LINDA VAHALA, ODU, Norfolk, GEORGE VAHALA, William & Mary, Williamsburg — Collisional damping of electrostatic electron Bernstein waves (EBWs) can play an important role in EBW applications for tokamaks. Electron temperature in the vicinity of the EBW-X-O mode conversion region may be low enough ($T_e \lesssim 15$ eV) to give rise to a significant collisional damping of EBWs, which have rather low group velocity. This can partially block EBW emission or EBW heating. Collisional damping has been investigated by ray-tracing and full-wave simulations, using various collisional terms in the dielectric tensor. The theory of collisional effects for wave propagation in hot magnetized plasmas is still incomplete and different models yield different results. Model results using NSTX experimental data are compared and importance of collisional damping to EBW emission from NSTX is discussed.

[1]Work Supported by AS CR project AV0Z-20430508, by USDOE DE-AC02-76CH03073, and by EURATOM.

TP8.00105 Mode conversion coupling to electron Bernstein waves[1] , D.S. BOONE, JR., A.K. RAM, PSFC, MIT — In NSTX, and generally in spherical tori, the emission of electron Bernstein waves (EBW) from the interior of the plasma can be observed in the vacuum region after mode conversion to the X mode and/or the O mode. The same mode conversion process comes into play when exciting EBWs through externally launched power. We consider the mode conversion process that couples the O mode to EBWs via the X mode. It is shown that density inhomogeneity can change the mode conversion efficiency significantly from that obtained analytically in [1]. Results obtained from a comprehensive model [2] are found to differ from the analytical result as the gradient scale length decreases. A detailed analysis comparing the analytical and computational results will be presented.
[1] E. Mjølhus, *J. Plasma Phys* **31**, 7 (1984).
[2] A. K. Ram and S. D. Schultz, Phys. Plasmas **7**, 4084 (2000).

[1]Work supported by DoE grants DE-FG02-91ER-54109 and DE-FG02-99ER-54521.

TP8.00106 Nonlinear Collisional Absorption of High-Harmonic Relativistic Electron Bernstein Modes in the Princeton Spherical Tokamak Plasma.[1] , V. STEFAN, Stefan University — It is shown that an efficient control of anomalous absorption in the Princeton Spherical Tokamak is possible, leading to a favorable convective R-EB harmonics excitation. In this model the driver pump in the electron cyclotron range of frequencies, O- or X-mode, excites relativistic Electron Bernstein Mode[2] harmonics (R-EB harmonics) in the edge region of ST plasma. Nonlinear relativistic EB harmonics, in turn, propagate toward the central region of the ST, whereby they are effectively absorbed in the electron cyclotron resonance region via nonlinear collisional damping. The scaling laws for the thermonuclear yield, ratio of the thermonuclear power to the external power, for the case of excitation of EB harmonics, n(EB) + (n-1) (EB), n= 5,6 harmonic number, and for the excitation of n(EB) + (UH), (UH) the upper hybrid mode, are obtained. The plasma-ignition criterion is analyzed in terms of O- and X-Mode power.

[1]Supported by Nikola TESLA Laboratories, La Jolla, CA 92038-2946

[2]V. Stefan, Anomalous Absorption of High-Harmonic Relativistic Electron Bernstein Modes in Spherical Tokamak Plasmas (Abstract ID: BAPS.2007.APR.S1.23; The American Physical Society, April-2007 Meeting, April 14-17, 2007, Jacksonville, Florida.

TP8.00107 GENERAL SPHERICAL TORUS —

TP8.00108 Overview of the Pegasus Experimental Program[1] , A.C. SONTAG, D.J. BATTAGLIA, M.W. BONGARD, N.W. EIDIETIS, M.J. FROST, G.D. GARSTKA, B.A. KUJAK-FORD, M.B. MCGARRY, B.J. SQUIRES, B.T. LEWICKI, E.A. UNTERBERG, G.R. WINZ, University of Wisconsin-Madison — The Pegasus Toroidal Experiment is exploring plasma stability at near-unity A and developing non-solenoidal startup tools. Several techniques have been developed to suppress deleterious tearing modes by modifying the current profile, including toroidal field ramps and noninductive current drive via washer-stack current sources. These techniques have allowed access to I_N=14 MA/m-T without the appearance of performance-limiting instabilities. Filamentary structures have recently been observed near the edge of almost all ohmic discharges; large values of $j_{||}/B$ in this region suggest that these may be the result of peeling modes. Non-inductive startup via washer-stack current sources has produced plasmas with toroidal currents up to 50 kA. Plasmas have been produced using two geometries: with sources in the lower divertor region, and with a source on the outboard midplane producing moderate-A targets intended for PF induction. Plasmas produced with both geometries have been successfully coupled to Ohmic drive.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

TP8.00109 Operations at High I_N in the Pegasus Toroidal Experiment[1] , E.A. UNTERBERG, D.J. BATTAGLIA, M.W. BONGARD, M.J. FROST, G.D. GARSTKA, A.C. SONTAG, University of Wisconsin-Madison — In efforts to define the operating space of a near-unity aspect ratio ST, the external kink boundary is explored by operating at high normalized current (I_N) and toroidal field utilization (I_P/I_{TF}). Recent experiments have accessed I_N up to 14 MA/m-T ($I_P/I_{TF} \sim 2.3$) through current profile manipulation. Three techniques are employed to access high I_N. The first two involve electrostatic current sources for helicity injection, while the third uses TF rampdowns. Equilibrium reconstructions indicate that two techniques are allowing dramatic changes in the current profile and the third is accessing high I_N through greater experimental flexibility. Mode analysis during the current manipulation experiments shows no consistent mode activity. The MHD activity that is observed appears to coincide with reduced shear at rational flux surfaces destabilizing tearing modes at higher m. This is opposed to earlier experiments with ohmic-only current drive where low-order tearing modes were universally observed, limiting I_N ($\sim$ 6-8 MA/m-T) and I_P/I_{TF} to unity. There has yet to be evidence of ideal MHD mode activity during these experiments giving encouragement than further gains in I_N can be made.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

TP8.00110 Nonsolenoidal startup of Pegasus plasmas using DC helicity injection and poloidal field induction[1] , B.J. SQUIRES[2], N.W. EIDIETIS, G.D. GARSTKA, A.C. SONTAG, G.R. WINZ, University of Wisconsin-Madison — The central solenoid of a spherical torus (ST) offers limited Ohmic flux, which exacerbates the limitations of this heating and current drive technique. The design of a scalable non-solenoidal (NS) startup technique is desired to expand the operating space of the ST and to provide a path to NS operation for STs and tokamaks. Pegasus employs a two-part NS startup technique of DC helicity injection and poloidal field induction. DC helicity injection is used to create a target plasma at the outboard midplane by injecting current along helical field lines. The current filaments relax to a tokamak-like magnetic topology with I_p determined by magnetic helicity conservation. A prototype system capable of injecting up to 2 kA has been used to create target plasmas with toroidal current up to 20 kA. Poloidal field induction has been used to ramp the target to 30 kA and provide a target suitable for coupling to other CD techniques.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375
[2]Research performed under appointment to the FES Fellowship Program administered by ORISE under a contract between the U.S. D.O.E. and the Oak Ridge Associated Universities

TP8.00111 Global energy confinement studies on the Pegasus Toroidal Experiment[1] , D.J. BATTAGLIA, M.J. FROST, G.D. GARSTKA, A.C. SONTAG, E.A. UNTERBERG, G.R. WINZ, University of Wisconsin-Madison — Recent studies have shown that low-recycling walls significantly enhance L-mode energy confinement [1]. Discharges on Pegasus suggest a low-recycling regime is obtained using titanium gettering and cryogenic pumping. When the external gas supply is terminated during an established discharge, tangential H_α and visible light signals drop to 5% of their initial levels within 5 ms. Wall recycling is measured using the density decay rate, and its effect on particle and energy confinement on Pegasus is explored. Initial global energy confinement times of $\tau_E = 2 - 4$ ms were calculated for $I_P \sim 0.15$ MA L-mode discharges. Scans of plasma current and line-averaged density are used to benchmark τ_E measurements against empirical L-mode scaling laws. These initial τ_E measurements indicate the H-mode power threshold as given by the ITPA04 scaling [2] can be exceeded in diverted Ohmic discharges on Pegasus.

[1] Majeski, R. *et al.* Phy. Rev. Lett. **97** 2006 075002
[2] Takizuka, T. *et al.* Plasma Phys. Control. Fusion **46** 2004 A227

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

TP8.00112 Initial Edge Stability Observations in the PEGASUS Toroidal Experiment[1] , M.W. BONGARD, D.J. BATTAGLIA, G.D. GARSTKA, A.C. SONTAG, E.A. UNTERBERG, University of Wisconsin-Madison — Edge stability is an important consideration for design of fusion experiments, as transient heat loads generated by edge instabilities may damage the first wall. Such instabilities are now believed to include peeling (current driven) and ballooning (pressure driven) components. Peeling instability may be expected for high values of edge $j_{||}/B$ and low edge pressure gradient. This matches the operating space of Pegasus, with typical $<j_{||}/B> \sim 100$ kA/m^2, $|B| \sim 0.01$ T, and an L-mode edge. A new camera system has observed filamentary structures in the edge of nearly all ohmically-heated discharges. Ideal stability analysis of these discharges with DCON indicates marginal stability to resistive interchange for $\psi_N \geq 0.95$. Modification of triangularity during startup is observed to delay instability onset. A plasma control system based on that used on DIII-D will allow study of the influence of plasma shaping on mode stability characteristics. An array of magnetic probes capable of insertion into the scrape-off layer and plasma edge is being developed to provide a local constraint on the edge current profile.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

TP8.00113 An Upgraded Soft X-ray Pinhole Camera for Current Profile Measurements on the Pegasus Toroidal Experiment[1] , M.B. MCGARRY, M.J. FROST, G.R. WINZ, A.C. SONTAG, University of Wisconsin-Madison — An improved soft X-ray pinhole camera for current profile measurement has been installed on Pegasus. With an optical CCD camera and P43 phosphor scintillator that responds to X-ray energies in the range of 100 eV-5 keV, it provides a 240-fold throughput improvement over the prototype (Tritz et al, Rev. Sci. Instrum., **74**, 2003, 2161). The 4k x 4k back-illuminated CCD has a 200 mm diameter active area, giving a spatial resolution of ∼3 cm at 1 m and a temporal window of 2 ms. The current profile is obtained iteratively. Abel inversion of the measured intensity is used to obtain an emissivity profile across the plasma midplane. This profile is then used as constraint on an equilibrium reconstruction program, which generates a set of potential current profiles and associated intensity contours. χ^2 minimization during the equilibrium fitting identifies the best intensity map. This non-invasive current profile measurement technique offers improved understanding of MHD mode evolution and has potential applications for large scale fusion experiments.

[1]Work supported by U.S. DOE Grant DE-FG02-96ER54375

TP8.00114 The Lithium Tokamak eXperiment (LTX) - Status and Plans[1] , R. KAITA, R. MAJESKI, L. BERZAK, T. GRAY, T. KOZUB, H. KUGEL, T. STRICKLER, J. TIMBERLAKE, J. YOO, L. ZAKHAROV, PPPL, J. AHN, R. DOERNER, UCSD, R. MAINGI, ORNL, V. SOUKHANOVSKII, LLNL — The LTX is the first toroidal device with a fully non-recycling wall almost completely surrounding the plasma. Such a plasma- facing component (PFC) is expected to lead to a new plasma regime with flat T_e profiles, and the LTX goal is to explore its confinement and stability. The LTX is a spherical tokamak designed to have R=40 cm, a=26 cm, B_t=3.4 kG, I_p=400 kA, T_e=1 keV, and T_i=200 eV, for discharges of 100 ms or more. It contains a shell with four segments, each made of 0.375″-thick copper and a 0.0625″-thick stainless steel liner. A lithium layer, up to 100 nm thick, will be vapor deposited on the liner between shots. For a non- recycling PFC, the lithium will be kept chemically active with a shell temperature above the lithium melting point. The first tokamak experiments with large area liquid lithium PFC's used a toroidal liquid lithium limiter in the Current Drive eXperiment - Upgrade (CDX-U). To compare with CDX-U results, initial experiments will be performed with a toroidal liquid lithium "pool" in the lower half of the LTX shell. Assembly of LTX is complete, and preparations for plasma operations are in progress.

[1]Supported by US DOE contract #DE-AC02-76CH-03073

TP8.00115 Plasma Performance with Lithium PFCs in CDX-U and Projections to LTX[1] , R. MAJESKI, R. KAITA, L. BERZAK, T. GRAY, H. KUGEL, D. MANSFIELD, J. SPALETA, J. TIMBERLAKE, J. YOO, L. ZAKHAROV, PPPL, G. PEREVERZEV, IPP-Garching, J. AHN, R. DOERNER, UCSD, R. MAINGI, ORNL, V. SOUKHANOVSKII, LLNL — Use of a large-area liquid lithium limiter in the CDX-U tokamak produced the largest enhancements in ohmic tokamak confinement ever observed [R. Majeski, et al., Phys Rev. Lett. 97, 075002-1- 075002-4 (2006]. Simulations of CDX-U have now been performed with the ASTRA code, utilizing a model with neoclassical ion transport and boundary conditions suitable to a nonrecycling wall, with fueling via edge gas puffing. This transport model reproduces the experimental values of the energy confinement, loop voltage, and density for a typical CDX-U lithium discharge. The model has been used to project the performance of the new Lithium Tokamak eXperiment (LTX), with fueling via edge gas puffing, and with the addition of core fueling via neutral beam injection (NBI). Core fueling with NBI in LTX, with a low recycling wall of liquid lithium, is predicted to result in core electron and ion temperatures of 1 - 2 keV, and energy confinement times in excess of 50 msec.

[1]Supported by US DOE contract #DE-AC02-76CH-03073

TP8.00116 Thomson Scattering Measurements on the Lithium Tokamak Experiment (LTX) , TREVOR STRICKLER, BENOIT LEBLANC, RICHARD MAJESKI, ROBERT KAITA, Princeton Plasma Physics Laboratory — Experiments are beginning on the Lithium Tokamak Experiment (LTX). The goal of LTX is to investigate tokamak plasmas that are almost entirely surrounded by walls coated in liquid lithium. Past results have shown that liquid lithium coatings on plasma facing components may behave as low-recycling boundary surfaces, which can fundamentally alter the behavior of the confined plasma. On CDX-U, results with lithium limiters indicated a reduction in the overall recycling coefficient and an increase in the confinement time. On LTX, it is expected that liquid lithium will result in higher temperatures at the plasma edge, flatter overall temperatures profiles, density profiles peaked near the plasma center, and an increase in confinement time. To test these predictions, the temperature and density profiles in LTX will be measured by a multi-point TVTS Thomson scattering system, in conjunction with microwave interferometry for density. Presently, the TVTS system for LTX offers up to 12 diagnostic channels to measure plasma conditions between the plasma edge and the plasma center. In the future, Thomson scattering measurements focusing on the edge conditions will be made at higher spatial resolution. *Supported by US DOE contract #DE-AC02-76CH-03073 and the ORISE Fusion Postdoctoral Fellowship

TP8.00117 Effects of Liquid Lithium Plasma Facing Components in the Lithium Tokamak eXperiment[1] , LAURA BERZAK, Princeton University, ROBERT KAITA, RICHARD MAJESKI, LEONID ZAKHAROV, Princeton Plasma Physics Laboratory — The LTX (Lithium Tokamak eXperiment) will investigate magnetically confined plasmas with liquid lithium walls, the first experiment of its kind. This unique first wall condition is expected to dramatically enhance confinement, stability, and discharge control, and virtually eliminate recycling. The LTX is currently under construction, with first plasma scheduled in late 2007. An extensive array of diagnostics will be available, including flux loops, Rogowskii coils, Mirnov coils, Thomson scattering, interferometry, and deposition monitors. This research project will focus on reconstructions of the LTX equilibrium, using magnetics measurements to constrain plasma modeling in the Equilibrium and Stability Code (ESC). This is the first code capable of equilibrium reconstructions using magnetic signals dominated by eddy current contributions from the surrounding walls. Of particular significance will be changes in the current profile as recycling is lowered, and its effect on the confinement time's dependence on plasma current, toroidal field, density, and temperature. In addition, this research will further knowledge of liquid metal walls for chamber technology in both inertial and magnetic fusion.

[1]Supported by US DOE contract #DE-AC02-76CH-03073

TP8.00118 Building a Lyman-α detector for measurement of recycling rates in LTX[1] , JONGSOO YOO, ROBERT KAITA, RICHARD MAJESKI, PPPL, JILL FOLEY, ENRIQUE MERINO, Nova Photonics — The measurement of the particle recycling rate is essential for understanding the performance improvements of lithium PFC devices like CDX-U and LTX. Recycling is usually measured by using atomic H-α (Balmer-α) emission, but the signal can be difficult to interpret because H-α has a high reflectivity for many wall materials including lithium. In contrast, Lyman-α is known to have a low reflectivity at a lithium wall. To measure recycling rates for LTX, a Lyman- α detector with a photodiode and a directly deposited 117-131nm pass-band filter has been developed. The detector has been tested with collisional beam excitations with a background of hydrogen gas. Based on known inelastic collision cross sections of a hydrogen beam, the relative intensity of Lyman- α collisionally induced fluorescence (CIF) to H-α CIF has been calculated. By comparing the theoretical ratio with the measured one, the detector can be calibrated.

[1]Work supported by US-DOE contract #DE-AC02-76CH03073.

TP8.00119 Recycling Coefficient Calculation for Discharges with Lithium Plasma-facing Surfaces in CDX-U[1] , T. GRAY, R. KAITA, R. MAJESKI, J. SPALETA, D. STOTLER, J. TIMBERLAKE, L. ZAKHAROV, Princeton Plasma Physics Lab — Recent experiments on the CDX-U spherical torus have successfully achieved a significant reduction in recycling with large-area liquid lithium plasma-facing surfaces. Modeling of low recycling discharges with DEGAS2, a neutral particle transport code, has been performed. Utilizing available spectroscopic data, this modeling allows a calculation of a global recycling coefficient (R) for the low recycling discharges. The R values deduced with the modeling are used with τ_p^* measurements to obtain estimates for the particle confinement time τ_p. Measurements of τ_p^* were performed by using transient gas puffing and observing the time dependence of the plasma density with microwave interferometry. An analysis of the impact of light reflections on the spectroscopic measurements will also be presented.

[1]Supported by US DOE contract #DE-AC02-76CH-03073.

TP8.00120 Spherical tokamak plasma startup by use of a washer gun , RYOTA IMAZAWA, RYOSUKE MORII, MAKOTO NAKAGAWA, YASUSHI ONO, University of Tokyo — Startup without a center solenoid(CS) coil is an important subject for spherical tokamak(ST) plasmas due to their narrow center coil space. The new spherical tokamak device UTST in University of TOKYO was designed to form ultra high beta STs using their axial merging. The CS-less startup for each ST was studied by the toroidal electric field induced by external poloidal field(PF) coils. We used a seed of plasma made by a washer gun together with PF coil current whose frequency is a few kHz, in order to make low q and high density ST. The washer gun was installed on the bottom of the vacuum vessel of UTST. A fast piezo valve was used to feed the working gas to the gun. The gas flow from it was as small as 500sccm and discharge time of the gun was as short as 1$\sim$2ms. So the gun discharge started after gas was filled in the vacuum vessel. However a plasma from the gun was supplied to the bottom 1/3$\sim$1/2 of the total volume because of recombination process. A new fast solenoid valve is being installed. Using a video camera, we observed a spiral light line from the gun. The plasma light was observed in large region of vacuum vessel and now proceeded to rogowsky coil measurement during the plasma formation.

TP8.00121 2-Dimensional Imaging Measurement for Pressure-Driven Instability in High Beta Spherical Tokamak , HEIZO IMANAKA, YOSHINORI HAYASHI, The University of Tokyo, EIITIRO KAWAMORI, National Cheng Kung Univesity, YASUSHI ONO, The University of Tokyo — We have been forming ultra-high-beta Spherical Tokamaks (ST) using reconnection heating of their axial merging in the TS-4 experiment, University of Tokyo. The produced ST was observed to have the maximum beta 50-60% right after the reconnection. An question is whether the pressure-driven instability dangerous for high-beta STs appears or not. Using two dimensions image camera, we detected line-shaped emission parallel to magnetic line at the plasma surface. These results agree with a characteristic of the ballooning instability that grows up locally with magnetic line. The two dimensions magnetic probe measurement enabled us to study s-alpha diagrams for the produced ST plasmas using the ballooning stability code. The line-shaped emission was found to appear only when its s-alpha parameters is located in unstable region for ideal ballooning mode. No line-shaped emission was detected when its s-alpha parameters is located in the stable regime. Further magnetic measurement will be made to clarify the localized mode in the high-beta state in addition to the imaging camera measurement.

TP8.00122 SIMULATION: HEDP/PLASMA ACCELERATOR/SPACE —

TP8.00123 Computational Efficiency and Parallelization Issues in ICF Calculations , DAVID FYFE, Naval Research Laboratory — The advent of commodity cluster computers has put a premium on being able to map physics codes onto the computer hardware efficiently. Here we discuss the issues surrounding a distributed memory implementation of NRL's radiation transport code, FASTRAD3D. FASTRAD3D includes hydrodynamic transport, inverse Bremsstrahlung laser energy deposition, real equation of state through table lookup, implicit thermal diffusion, and a multi-group variable Eddington diffusion radiation transport model. Parallelization is accomplished through domain decomposition, but the data dependencies in some of the physics models can influence the type of domain decomposition. Load balancing issues arise in the implementation of the equation of state, where multi-material regions can take longer than single material regions. Implicit solvers and pre-conditioners associated with the elliptic solvers can impact the parallel efficiency. Finally, effective cache management can improve performance.

TP8.00124 DRACO Development for Modeling 3D Instabilities[1] , MILAD FATENEJAD, University of Wisconsin - Madison, TIMOTHY COLLINS, U. of Rochester - Laboratory for Laser Energetics, GREGORY MOSES, University of Wisconsin - Madison, RADHA BAHUKUTUMBI, PATRICK MCKENTY, VLADIMIR SMALYUK, U. of Rochester - Laboratory for Laser Energetics — Additional features have been included in the DRACO Lagrangian radiation hydrodynamics code enabling realistic 3D simulation of laser driven ablation, shocks, and fluid instabilities in low-Z plasmas. Since last reported (Fatenejad and Moses, Bull. APS 51, 209(2006).), DRACO now includes 3D laser ray tracing to model laser absorption and hydrodynamic restoring forces to counteract artificial grid distortions. Two temperature (electron and ion) flux-limited thermal transport has been included. DRACO is now being used to model the acceleration of a slab of Cu-doped Be into liquid deuterium via laser ablation. The slab has single mode perturbations imposed on it both at the ablation front and at the D-Be interface. Preliminary simulations of fluid instability growth will be presented using the improved DRACO 3D modeling. These simulations are motivated by similar recent experiments performed at the OMEGA laser facility.

[1]Work Supported By: University of Rochester - Laboratory for Laser Energetics

TP8.00125 Experiments to validate self-consistent beam-gas-electron code[1] , A.W. MOLVIK, W.M. SHARP, LLNL, M. KIREEFF COVO, LLNL and UCB, R.H. COHEN, A. FRIEDMAN, S.M. LUND, LLNL, J.-L. VAY, J.E. COLEMAN, F.M. BIENIOSEK, M.A. FURMAN, P.K. ROY, P.A. SEIDL, LBNL — The WARP-POSINST model tracks beam ions and secondary particles (ions, electrons, gas molecules) in a self-consistent manner with techniques developed for heavy-ion fusion and e-cloud studies in high-intensity accelerators. We have developed simple experiments to exercise the code. Heavy-ion beams striking a surface cause gas desorption and electron emission, both of which can limit beam performance. Subsequent beam ions can ionize the gas, producing additional electrons. Two parallel plates, on either side of the beam and orthogonal to the end wall, are biased as a dipole: one grounded and the other biased to $\pm$ 10 kV. The electron current to a positive plate jumps to the electron emission value; then ramps slowly due to ionization of desorbed gas. This is a rigorous test of the particle dynamics of the model and constrains the secondary particle production coefficients.

[1]This work performed under the auspices of the U.S DOE by Univ. of Calif., LLNL and LBNL under contracts W-7405-Eng-48 and DE-AC02-05CH11231.

TP8.00126 Simulation of the Spectral Properties of Materials with PrismSPECT , JOSEPH MACFARLANE, I. GOLOVKIN, P. WANG, P. WOODRUFF, Prism Computational Sciences, J. BAILEY, T. MEHLHORN, G. ROCHAU, Sandia National Laboratories — PrismSPECT is a collisional-radiative spectral analysis code designed to simulate the atomic and radiative properties of LTE and non-LTE plasmas over a wide range of conditions. For a grid of user-specified plasma conditions, PrismSPECT computes spectral properties (emission and absorption), ionization fractions, atomic level populations, and line intensity ratios. PrismSPECT can compute the properties of plasmas irradiated with external radiation fields, and plasmas with non-Maxwellian electron distributions, and is capable of simulating inner-shell (e.g., K-alpha and K-beta) satellite line emission. PrismSPECT has been used in the analysis of spectra spanning a wide range of conditions. We will present results from the analysis of high-temperature Fe opacity data obtained in dynamic hohlraum experiments at Sandia National Laboratories, as well as spectra obtained from low-temperature laser-produced plasma experiments.

TP8.00127 Collision Models for Plasma Simulation of Thermonuclear Burn: Comparison of Models and Applications , DAN WINSKE, BRIAN ALBRIGHT, KEVIN BOWERS, DON LEMONS, Los Alamos National Laboratory — There is renewed interest in examining plasma physics issues related to thermonuclear burn in inertial confinement fusion (ICF) and fast ignition (FI): e.g., the rate of temperature equilibration of electrons and ions, the formation and/or depletion of high energy tails of ion velocity distributions of ions, the slowing of energetic ions in dense plasmas, etc. To address these types of questions, we have developed a new particle-in-cell (PIC) plasma simulation capability, embodied in the code VPIC. To model TN-burn problems in dense plasmas, we have developed a new Coulomb collision model, based on the use of stochastic differential equations and well-known Spitzer rates to describe the collision process, which was presented at last year's meeting. Here we extend the model to included arbitrary weighting of individual simulation particles, rather than just separate weights for each plasma species, which is a feature intrinsic to VPIC. We compare test cases for plasma relaxation and slowing of fast beams using the new collision model with results obtained from an extension of standard particle-pairing collision models to weighted particles for parameter regimes of interest to ICF and FI.

TP8.00128 Tests for Krook model for nonlocal heat transport in laser produced plasmas[1] , D. COLOMBANT, W. MANHEIMER, M. KESKINEN, Plasma Physics Division, Naval Research Laboratory, Washington, DC, V. GONCHAROV, Laboratory for Laser Energetics, University of Rochester, Rochester, NY — A Krook model has recently been proposed [1] for solving the problem of electron energy transport in laser produced plasmas. In this work, we report on comparisons of this model with 1) a more complete Fokker-Planck model and 2) an experiment performed at NRL [2]. A simple test problem solved with a Fokker-Planck code was first considered by Matte and Virmont [3]. It consists of a pure heat transport problem in a uniform plasma slab between two thermostatic walls at different temperatures. The normalized slab length (L/λ where λ is the average electron mean free path) varies from order 1 to a few hundreds. The comparison with experiment involves the back side temperature measurement behind a 58 μm plastic foil after the passage of a laser-produced shock wave. Results from these two comparisons will be presented and outline for further work will be discussed.

[1] W.Manheimer, D.Colombant and V.Goncharov, submitted to Phys. of Plasmas
[2] E.McLean et al., Optics Comm. 166, 141 (1999)
[3] J.P.Matte and J. Virmont, Phys. Rev. Letters 49, 1936 (1982)

[1]This work was supported by U.S. Departent of Energy.

TP8.00129 Generation of nonadiabatic laser pulse front from an overdense plasma , MIN SUP HUR, VICTOR KULAGIN, KERI, HAE JUNE LEE, Pusan National University, JAEHOON KIM, HYYONG SUK, KERI — We suggest utilizing the interaction of an overdense plasma and an ultraintense laser pulse to generate extremely sharp (nonadiabatic) ramping-up of the pulse front. Due to the relativistic mass increase, the overdense plasma becomes partially transparent. As the boundary between the transparent and opaque region moves with a slow velocity, the laser pulse keeps being reflected by the boundary. After propagating through a couple of microns, the initial Gaussian pulse shape results in half-Gaussian shape. The different characteristics between the linear and circularly polarized pulse are discussed.

TP8.00130 Plasma Heating by Intense Electron Beams in Fast Ignition , NATHAN SIRCOMBE, AWE plc, MARK SHERLOCK, ROBERT BINGHAM, PETER NORREYS, CLF, Rutherford Appleton Laboratory — Collisionless electron beam-plasma instabilities are expected to play an important role in fast ignition. Such beams are produced by the short high power ignition laser interacting with long scale length plasmas. Here we present results from a one dimensional Vlasov-Poisson code used to investigate different electron beam temperatures and background plasma conditions. The simulations demonstrate that the beam-plasma instabilities drive large amplitude electrostatic waves that undergo the parametric decay instability driving backwards propagating electrostatic waves and much lower frequency ion acoustic waves. Saturation of the beam-plasma instability creates a plateau in the electron distribution function consistent with quasi-linear theory. We observe the creation of high energy tails in the electron and ion distribution functions, formed by the trapping of particles in the waves formed during the collapse of the beam. At the highest electron-beam temperatures we observe the formation of coherent phase-space structures - a direct consequence of the cascade nature of the parametric instability. These simulations are clearly beyond a simple quasi-linear treatment and demonstrate the transfer of energy from an incident beam to the ion population via collisionless effects. Implications of these mechanisms to the fast ignition scheme will be discussed.

TP8.00131 Using Mixtures of Ion Species to Control Stimulated Brillioun Scattering[1] , RICHARD BERGER, S.H. GLENZER, L. DIVOL, M. ROSEN, N.B. MEEZAN, D. CALLAHAN, Lawrence Livermore National Laboratory — Predicted plasma conditions in ignition targets, planned for the National Ignition Facility (NIF), have the potential to produce stimulated Brillouin Scattering (SBS) of the incoming laser light. Large SBS reflectivity is predicted from some NIF ignition designs. The SBS interaction takes place in hot ($T_e \sim$ 5keV) gold plasma a few hundred microns long in which ion acoustic waves are weakly damped. We show that adding a small fraction of low atomic mass material, *e.g.* Boron, increases the calculated damping significantly and reduces the predicted SBS reflectivity dramatically without affecting the radiation temperature. SBS in mixtures of low-atomic-number species plasmas is well understood both experimentally and theoretically. We will discuss some of the additional effects that collisions in high-Z plasma have on linear and nonlinear ion wave response.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

TP8.00132 Mitigation of Ion Motion in future Plasma Wakefield Accelerators[1] , REZA GHOLIZADEH, TOM KATSOULEAS, PATRIC MUGGLI, University of Southern California, WARREN MORI, University of California Los Angeles — Simulation and analysis of the ion motion in a plasma wakefield accelerator is presented for the parameters required for a future ILC afterburner. We Show that although ion motion leads to substantial emittance growth for extreme parameters of future colliders in the sub-micron transverse beam Size regime, several factors that can mitigate the effect are explored. These include synchrotron radiation damping, plasma density gradients and hot plasmas.

[1]This work was supported by Department of Energy Contract No. DE-FG02-92ER40745.

TP8.00133 Laser wakefield simulation using a speed-of-light frame envelope model[1] , BENJAMIN COWAN, DAVID BRUHWILER, AMMAR HAKIM, PETER MESSMER, PAUL MULLOWNEY, Tech-X Corporation, ERIC ESAREY, Lawrence Berkeley National Laboratory — Simulation of laser wakefield accelerator (LWFA) experiments is computationally highly intensive due to the disparate length scales involved. Current experiments extend hundreds of laser wavelengths transversely and thousands in the propagation direction, making explicit PIC simulations enormously expensive and requiring massively parallel execution in 3D. We can substantially improve the performance of laser wakefield simulations by modeling the envelope modulation of the laser field rather than the field itself. This allows for much coarser grids, since we need only resolve the plasma wavelength and not the laser wavelength, and therefore larger timesteps. Thus an envelope model can result in savings of several orders of magnitude in computational resources. Secondly, coherent transition radiation (CTR) from an electron bunch exiting the plasma region of an LWFA is a useful experimental diagnostic, and we wish to investigate the dependence of CTR properties on the bunch properties. Modeling the laser envelope separately from the fields due to the plasma particles allows examination of the CTR, making systematic studies possible. Finally, previous simulations evolving the envelope in the lab frame showed distortions when the laser pulse was propagated over long distances in a plasma. By propagating the laser envelope in a Galilean frame moving at the speed of light, these distortions can be avoided and simulations over long distances become possible. Here we describe the model and its implementation, and show simulations of laser wakefield phenomena such as trapping, acceleration, and CTR using the model.

[1]Work supported by the U.S. DOE Office of Science, Office of High Energy Physics, under grant DE-FG02-04ER84097.

TP8.00134 Numerical simulation of microwave transmission in the presence of an electron cloud , KIRAN SONNAD, LBNL, SETH VEITZER, PETER STOLTZ, Tech-X Corporation, MIGUEL FURMAN, LBNL, JOHN CARY, Tech-X Corporation — Electron cloud effects on the transmission of microwaves through beam pipes in the CERN SPS experiment and the PEP-II Low Energy Ring (LER) at SLAC have been recently observed. Electrons within the vacuum chamber generated primarily via secondary electron emission have been observed to cause a phase shift in microwaves injected into the vacuum chamber. Understanding this effect may provide a useful diagnostic tool for measuring electron cloud densities in accelerators. We present numerical simulation results generated by the electromagnetic Particle-In-Cell (PIC) code VORPAL, which predicts this phase shift. We also measure the effects of non-uniform electron cloud density and externally applied magnetic fields on the transmission properties, and compare our predictions to recent experiments at the PEP-II LER.

TP8.00135 High order methods for electromagnetics simulation , JOHN LOVERICH, AMMAR HAKIM, Tech-X Corporation — Higher order methods in electromagnetics are of interest to the PIC community in modeling electromagnetic wave propagation in cavities. It is believed that high order numerical methods have advantages over lower order methods as they can produce equivalently accurate solutions at lower resolution and thus potentially at lower computational cost. In this paper we present the algorithm and result of electromagnetic simulations of the crab cavity using a higher than second order numerical wave propagation algorithm. Ultimately this high order scheme will be implemented in the plasma code VORPAL where it will be tested on a variety of computational plasma problems.

TP8.00136 Advances in electron emission from conformal boundaries in the VORPAL code , CHET NIETER, DAVID N. SMITHE, PETER H. STOLTZ, PAUL MULLOWNEY, KEVIN PAUL, JOHN R. CARY[1], Tech-X Corporation — Simulations of high-power microwave devices (HPM) involve the interaction of electrons with complex metal boundaries. Particle-in-Cell (PIC) methods are often used to model electrons when the velocity distribution is non-Maxwellian. The interaction of the PIC particles with the surfaces and the associated surface fields can be very challenging. We present recent advances in modeling electron surface effects at complex boundaries using the VORPAL code. These include accurate interpolation of the fields in cut cells on the boundary, secondary electron emission from conformal surfaces, and field emission of electrons from these surfaces. Discussion of the relevance to simulations of HPM devices with also be presented.

[1]also at University of Colorado

TP8.00137 Benefits of Higher-Order Particle Shapes in the Electromagnetic PIC Code VORPAL[1] , KEVIN PAUL, DAVID BRUHWILER, PAUL MULLOWNEY, PETER MESSMER, JOHN CARY, Tech-X Corporation, CAMERON GEDDES, ESTELLE CORMIER-MICHEL, ERIC ESAREY, Lawrence Berkeley Lab — Noise is one of the largest hurdles that particle-in-cell (PIC) codes must overcome in order to resolve such phenomena as particle trapping in laser wakefield acceleration (LWFA) and laser-solid interactions in fast ignition fusion scenarios. Using higher-order particle shapes has been shown to substantially reduce this noise. We present results of the implementation of higher-order particle shapes in the electromagnetic and electrostatic PIC code VORPAL, showing the benefits in application to LWFA and laser-solid interactions.

[1]Work supported by the U.S. DOE Office of Science, Office of High Energy Physics, under grants DE-FG02-06ER84484 (PICA) and DE-FG02-05ER84173 (HighZ).

TP8.00138 Designing an RF thruster booster unit with TOPICA[1] , VITO LANCELLOTTI, GIUSEPPE VECCHI, RICCARDO MAGGIORA, Politecnico di Torino — Electromagnetic (RF) plasma-based propulsion systems have gained increasing interest, as able to yield continuous thrust and controllable and wide-ranging exhaust velocities. An RF plasma thruster essentially features a plasma source, a booster unit and a magnetic nozzle. The usual choice for the booster is the ion-cyclotron resonance heating (ICRH), a well-established technology in fusion experiments to convey RF powers to magnetized plasmas. To help design the booster unit, TOPICA was extended to deal with magnetized cylindrical inhomogeneous plasmas [1]. The latter required a new module in charge of solving Maxwell's equations within the plasma to obtain the pertinent Green's function in the Fourier domain, i.e. the relation between the transverse magnetic and electric fields at the air-plasma interface. Calculating the antenna impedance—and hence the plasma loading—relies on an integral-equation formulation and subsequent finite-element weighted-residual scheme to evaluate the current density distribution on the conducting bodies and at the air-plasma interface. In this work the design of an ICRH stage with TOPICA is discussed.
[1] V. Lancellotti *et al.* (2007) *Proc. Joint Propulsion Conf.* AIAA-2007-5129

[1]Work funded by European Space Agency.

TP8.00139 Numerical Model of a Spacecraft Shielding against High-Energy Particles , ADRIAN SUN, Northrop Grumman, Redondo Beach, CA 90278, OLEG BATISHCHEV, MIT, Cambridge, MA 02139 — Galactic Cosmic Rays are composed of predominantly GeV protons and α-particles coming uniformly with $\sim$1 (m^2 sr sec MeV/nucleon)$^{-1}$ flux. Despite very low particle & power fluxes delivered, they pose a major continuous hazard for subjects, biological materials and sensitive equipment in space. A self-consistent adaptive kinetic model is being developed to simulate different strong magnetic, electrostatic and hybrid shielding schemes. The model includes relativistic transport of particles, calculation of internal electromagnetic fields, ambient and incidental plasma responses to the applied strong fields. Numerical method uses unstructured adaptive grids in 3D, enabling automatic capturing of important physical details of the shield and plasma. The numerical method applications using shared and distributed architectures will be discussed. Results of the kinetic simulations of a spacecraft shielding against high-energy particles and possible macro-particles will be presented.

TP8.00140 Numerical Study of Energy Release in Magnetized Corona Driven by Continuous Footpoint Motions , YI-MIN HUANG, ELLEN ZWEIBEL, DALTON SCHNACK, University of Wisconsin, Madison, ZORAN MIKIC, Science Applications International Corporation — The solar corona is a highly conducting plasma (Lundquist number $S \sim 10^{10-13}$). As such, Ohmic dissipation is negligible except within thin current filaments. In his coronal heating model, Parker suggests that thin current filaments can be induced in a magnetized corona via the shuffling of the field lines driven by continuous footpoint motions. One of the major difficulties in assessing the feasibility of Parker's mechanism is that the realistic parameters are way beyond the reach of current computer simulations. One possible approach is to establish the parametric dependence of the dissipation rate through simulations of attainable parameters. We study the Parker's model in two settings: (1) time independent footpoint twisting, and (2) footpoint shearing in alternating directions with random phases. Thin current filaments are created in both cases, and the system finally settles to a statistical steady state in which the Poynting power influx balances the viscous and resistive dissipation. Both configurations have only three relevant dimensionless parameters : Lundquist number, the aspect ratio, and the ratio between the Alfven transit time and the eddy turnover time. The parametric dependence of the dissipation power, as well as the similarities and differences between the two settings are discussed.

Thursday, November 15, 2007 9:30AM - 11:50AM –

Session TM5 Mini-conference on the First Microns of the First Wall: Mixed Materials Issues

Rosen Centre Hotel Salon 11/12

9:30AM TM5.00001 Review of C-Be mixed material plasma experiments in PISCES-B[1] , J. HANNA, D. NISHIJIMA, R.P. DOERNER, M. BALDWIN, K.R. UMSTADTER, R. SERAYDARIAN, R. HERNANDEZ, University California, San Diego — The current ITER design employs a Be first wall, and a W divertor with C strike points. ITER also calls for severe heat loads on these plasma-facing components. A beryllium-seeded deuterium plasma is used in PISCES-B to investigate mixed-material erosion and redeposition properties of ITER relevant divertor materials. Ongoing experiments using C samples in these Be-seeded deuterium plasmas will be reviewed. Of specific interest is the formation of beryllium carbide on the sample surface that effectively mitigates C chemical erosion. Changes in hydrogen retention in the samples due to mixed-material layer formation will also be discussed. Effects of transient heating of the samples to simulate surface temperature excursions on the carbide layer formation and hydrogen retention will also be presented.

[1]This work was supported by grant DE-FG02-07ER-54912 from the US DoE.

9:50AM TM5.00002 Mixed plasma species effects on Tungsten[1] , MATT BALDWIN, RUSS DOERNER, DAISUKE NISHIJIMA, University of California San Diego, YOSHIO UEDA, Graduate School of Engineering, Osaka University, Japan — The diverted reactor exhaust in confinement machines like ITER and DEMO will be intense-mixed plasmas of fusion (D, T, He) and wall species (Be, C, W, in ITER and W in DEMO), characterized by tremendous heat and particle fluxes. In both devices, the divertor walls are to be exposed to such plasma and must operate at high temperature for long durations. Tungsten, with its high-melting point and low-sputtering yield is currently viewed as the leading choice for divertor-wall material in this next generation class of fusion devices, and is supported by an enormous amount of work that has been done to examine its performance in hydrogen isotope plasmas. However, studies of the more realistic scenario, involving mixed species interactions, are considerably less. Current experiments on the PISCES-B device are focused on these issues. The formation of Be-W alloys, He induced nanoscopic morphology, and blistering, as well as mitigation influences on these effects caused by Be and C layer formation have all been observed. These results and the corresponding implications for ITER and DEMO will be presented.

[1]US-EU Collaboration on Mixed Materials and DOE Grant # DEFG02-07ER54912

10:10AM TM5.00003 Sputtering, impurity transport, and redeposition at the divertor and first wall[1] , JEFFREY N. BROOKS, Argonne National Laboratory — These wall-related processes are critical for ITER and future fusion reactor plasma facing component surfaces. REDEP/WBC code-package full kinetic, 3-D Monte Carlo calculations (with typical input of UEDGE/DEGAS plasma edge parameters and TRIM-SP sputter yields/distributions) are used to study the sputtering erosion/redeposition process. A major issue is formation of mixed surface materials e.g., Be/C or Be/W, and resulting sputtering, thermomechanical, and tritium codeposition properties. Generally, divertor-sputtered tungsten is highly locally redeposited with essentially zero net sputter erosion and plasma contamination predicted. Beryllium and physically sputtered carbon travel farther, but are still confined to the near-surface divertor region. In contrast, chemically sputtered divertor carbon and wall-sputtered material of any type can travel much further, with implications for T/C and T/Be codeposition, and Be or W wall-to-divertor transport and mixing.

[1]Work supported by US DOE Office of Fusion Energy Sciences

10:30AM TM5.00004 Hydrogenic Fuel Retention in Refractory Metals , D.G. WHYTE, B. LIPSCHULTZ, J. IRBY, PSFC-MIT, G.M. WRIGHT, FOM-Rijnhuizen — High-Z refractory metals such as tungsten and molybdenum (Mo) are favored as plasma-facing components in burning plasma experiment to minimize hydrogenic (H) fuel retention, mainly due to their low H solubility (~1 appm). Fuel retention in Mo has been measured and modeled in the Mo-tile Alcator C-Mod tokamak, and DIONISOS a new facility that features simultaneous plasma bombardment and real-time retention diagnosis in the first 10 microns of the material. We find that high ion fluxes and the requirement for surface recombination into D2 in order to release the deuterium, leads to a type of "pressure-induced" trap formation $> 1\%$ concentration in the metals; i.e. much larger than the solubility. Exposure in tokamaks leads to temperature transients through plasma heating and neutron bombardment that also increase retention. High temperature drives D traps permeation into the Mo, but the sudden cooling of the material with removal of the plasma flux "freezes" the D deep in the Mo which can only be released by temperatures significantly higher than obtained during plasma exposure. Nuclear displacements by high-energy particles (neutrons, ~MeV ions) also lead to damage sites that greatly enhance retention. These retention mechanisms occur in the bulk of the material, and are fundamentally different than co-deposition of D with surface films. Implications for burning plasma experiments will be discussed.

10:50AM TM5.00005 Effect of impurities on the thermo-oxidative removal of codeposits from DIII-D and JET divertor tiles[1] , A.A. HAASZ, C. TSUI, J.W. DAVIS, University of Toronto, Inst. Aerosp. Studies — Results are presented for the thermo-oxidative removal of codeposits from DIII-D and JET divertor tiles. The DIII-D codeposits are relatively thin (1-2 μm) and contain B impurities (0-45%), while the JET codeposits are thick (up to ~250 μm) and contain up to ~75% Be. Erosion rates, D-removal rates and the remaining D content in the codeposits were measured as a function of (i) pressure (2.1-79 kPa), (ii) temperature (523-673 K), and (iii) oxidation time (15 min to 8 h). The DIII-D results show that for C-D codeposits with less than a few percent B, it is possible to remove >95% of the D content in the codeposit in 15 minutes. The D-removal rate decreases with higher levels of B concentration. Our first results for the 'thick' Be-containing JET codeposits suggest that the initial rate of D removal is much higher for these thicker codeposits than for the previously studied relatively 'thin' (1-2 μm) DIII-D and JET deposits. This is despite the large Be concentration. Implications for ITER will be discussed.

[1]Funding was provided by NSERC, Canada.

11:10AM TM5.00006 Innovative Tokamak First Wall and Divertor Material Concepts[1] , C.P.C. WONG, General Atomics — For ITER design, the design guidance is to apply a Be layer on the plasma facing chamber surface. When extrapolated to DEMO design, the Be layer will not be suitable due to radiation damage. Similarly, a carbon surface will not be suitable due to high physical and chemical erosion rates, radiation damage of the material and potential large retention of tritium. Unfortunately, the remaining commonly proposed material, tungsten (W), could suffer radiation damage from α-charged particle implantation and experience blistering at the first wall and the formation of submicron fine structure at the divertor, which could result in W transport to the plasma core and severely limit the core performance. To resolve this potential impasse, an invention on the use of boron-infiltrated W-mesh surface is proposed to withstand ELMs and disruptions while retaining the capability of transmitting high-grade heat for power conversion. To make this concept work, in-situ boronization will be needed. Innovative first wall and divertor material concepts will be reviewed and initial development and identified requirements for the BW-mesh concept will be reported.

[1]Supported by the US DOE under DE-FC02-04ER54698.

11:30AM TM5.00007 Evolution of Elemental Composition and Morphology in Fusion Reactor's First Wall , YONG W. KIM, Lehigh University — Forcing of a multi-element alloy by a gradient field can modify the spatial profile of its elemental composition. The gradient field may be in the imposed temperature or the flux of impinging particles. In a fusion device, both scenarios apply. The consequences must be well understood because they change the thermal transport properties as well as the strength, corrosion and wear characteristics of the first wall materials. Given the large number of directions material evolution can take, new robust methods of near-surface composition analyses are needed. This paper presents a new measurement methodology and requisite instrumentation, which can provide measures of local elemental composition and transport properties simultaneously by time-resolved spectroscopy of laser-produced plasma (LPP) plume emissions from the specimen surfaces. The studies to date show that the composition profiles can be modified thermally in a reproducible manner; disparate thermal transport of constituent atoms can incur modifications of near-surface composition profiles.[Y.W. Kim, Int. J. Thermophysics **28,** 732 (2007)] Also, disparate fluxes of fuel particles, fusion products and impurities force the first walls in myriad ways. Repetitive application of the LPP analysis can resolve the near-surface composition profile as well as transport properties over several microns with depth resolutions to 20 nm. Work supported in part by NSF-DMR.

Thursday, November 15, 2007 2:00PM - 5:00PM –
Session UI1 MHD Rosen Centre Hotel Junior Ballroom

2:00PM UI1.00001 Progress in understanding error-field physics in NSTX spherical torus plasmas[1] , JONATHAN MENARD, PPPL — The low aspect ratio, low magnetic field, and wide range of plasma beta of NSTX plasmas provide new insight into the origins and effects of magnetic field errors. An extensive array of magnetic sensors has been used to analyze error fields (EFs), to measure error field amplification (EFA), and to detect resistive wall modes (RWMs) in real time. The measured error-field threshold for the onset of locked modes shows a linear scaling with plasma density, a weak dependence on B_T, and a positive scaling with magnetic shear. These results extrapolate to a favorable threshold $\delta B_{21}/B_T > 1\times10^{-4}$ for ITER. For these low-beta locked-mode plasmas, perturbed equilibrium calculations find that the plasma response must be included to explain the empirically determined optimal correction of NSTX error fields [1]. In high-beta NSTX plasmas exceeding the n=1 no-wall stability limit where the RWM is stabilized by plasma rotation, active suppression of n=1 EFA and correction of newly discovered n=3 error fields have led to sustained high rotation and record durations free of low-frequency core MHD activity. For sustained rotational stabilization of the RWM, both the rotation threshold and magnitude of EFA are important. At fixed normalized dissipation, kinetic damping models predict rotation thresholds to scale nearly linearly with particle orbit frequency. Studies for NSTX find orbit frequencies at large minor radius are a factor of two higher than used in the present kinetic damping theory derived in the limit of high aspect ratio and circular plasma cross-section. Such discrepancies may explain the recent observation of kinetic damping models under-predicting the critical rotation [2].

[1] J.K. Park, et al., "Correction of magnetic field errors in tokamaks", submitted to PRL (2007)
[2] H. Reimerdes, et al., Phys. Rev. Lett. 98, 055001 (2007)

[1]Work supported by US DOE Contract DE-AC02-76CH03073.

2:30PM UI1.00002 Neoclassical toroidal viscosity and error-field penetration in tokamaks[1] ,

ANDREW COLE, University of Wisconsin, Madison, WI 53706 — A model for field error penetration is developed that includes both resonant and non-resonant perturbed 3-D magnetic fields [1]. The non-resonant components give rise to a global neoclassical toroidal viscous [NTV] torque while a single resonant component produces a localized electromagnetic braking torque on its respective resonant surface. The NTV torque tries to keep the plasma flowing at a rate comparable to the ion diamagnetic flow. A phenomenological cross-field viscosity is included which resists the resonant electromagnetic torque in the vicinity of the resonant surface. Steady-state toroidal momentum balance across the resonant layer gives a solubility condition determining the "critical" resonant error-field strength—termed the *penetration threshold*—above which rotational shielding is lost and the resonant surface locks to the lab frame. Such locking occurs in low-density start-up tokamak plasmas [2], leading to plasma disruptions or confinement degradation and is a key issue for ITER. The toroidal momentum balance equation admits a WKB-type solution which implies that NTV acts to enhance cross-field viscosity in the vicinity of the resonant surface. This enhancement makes the plasma less sensitive to error-field penetration than previously predicted [3]. In particular, if $\tau_E \propto n_e$ (neo-Alcator-like) and the perpendicular momentum confinement time has no density dependence, we find the penetration threshold scales linearly with electron density—a result giving quantitative agreement for the first time between theory and experiment [2].

[1] A.J. Cole, C.C. Hegna, and J.D. Callen, to be published in PRL (2007).
[2] S.M. Wolfe, I.R. Hutchinson, et al., Phys. Plasmas **12**, 056110 (2005) and refs. cited therein.
[3] A.J. Cole and R. Fitzpatrick, Phys. Plasmas **13**, 032503 (2006) and refs. cited therein.

[1]Work funded by U.S. DoE Grant Nos. DE-FG02-86ER53218 and DE-FG02-92ER54139.

3:00PM UI1.00003 Extrapolating Neoclassical Tearing Mode Physics to ITER – Physics Basis and Experimental Comparison[1] ,

RICHARD BUTTERY, EURATOM/UKAEA Fusion Association, Culham Science Centre, Oxfordshire, UK. — Neoclassical Tearing Modes (NTMs) represent one of the most serious concerns for baseline and hybrid scenario performance in ITER. Already on present devices they limit attainable β, degrading confinement and causing disruptions. The concern is increased for ITER where stabilising small island and rotation effects are likely to be reduced. In this paper we review the physics basis for NTM scalings, and compare to experimental behaviour, to deduce the key effects and impact on ITER prediction. The principal criteria for NTM onset is dictated by a competition between stabilising small island effects, and the drive from NTM-triggering MHD (eg. sawteeth). Typically the former arise from orbit and transport effects when island sizes are comparable to ion banana widths. This suggests a lowering of NTM β thresholds as ITER-like ρ_i^*s are approached. In addition, reduced plasma rotation will increase NTM coupling to other instabilities and decrease stabilising effects due to wall and rotation shear. New studies on JET and DIII-D have highlighted this with falls of ~30% in both m/n=3/2 and 2/1 NTM β thresholds as momentum injection is removed. Indeed, a wide body of work confirms many aspects of the theory, particularly the expected small island effects and ρ_i^* scalings, while more detailed examinations, for example locally perturbing rotation with error fields, begin to distinguish particular physics mechanisms such as ion polarisation current effects. Thus consideration of the stabilising elements points to a lower metastability threshold for the NTM in ITER. Nevertheless, the triggering mechanisms provide grounds for optimism. For the most serious 2/1 NTM, onset in hybrid, and possibly baseline, scenario appears related to proximity to ideal β limits. Conversely, modes triggered by core MHD may be managed by proven control techniques for the core MHD itself.

[1]This work was jointly supported by the UK EPSRC and EURATOM under EFDA, and the US DOE under contract DE-FC02-04ER54698.

3:30PM UI1.00004 Advancing Tokamak Physics with the ITER Hybrid Scenario on DIII-D[1]

, P.A. POLITZER, General Atomics — Recent DIII-D experiments using hybrid scenario plasmas (hybrids) have furthered our understanding of transport and stability in high beta tokamaks, leading to the possibility of high fusion performance on ITER. The hybrid is a stationary, inductively driven, $q_0 \sim 1$ discharge with better confinement and stability than standard H-mode. Providing stationary, high beta conditions, the hybrid is an excellent configuration for study of tokamak plasma physics under conditions of interest to burning plasmas, such as low rotation, balanced T_{e} and T_{i}, shaping, and pedestal behavior. Compared to a standard H-mode, the hybrid has a broader current profile, reducing or eliminating the deleterious effects of sawteeth, and is less susceptible to $m/n = 2/1$ NTMs, allowing higher β operation. Our experiments have conclusively shown that the current profile is broadened by a relatively benign $m/n = 3/2$ NTM. Power balance in hybrids is dominated by electron heat conduction, but the observed electron thermal diffusivity is relatively small, and the ion thermal diffusivity is consistently at or close to the neoclassical value. Using the recent modification to the DIIID neutral beam configuration, we have been able to reduce the toroidal rotation velocity to a central Mach number <0.1, under stationary conditions. We find that confinement improves with increasing rotation. Gyrofluid simulations indicate that this is associated with the change in ExB flow shear. The width of the NTM island decreases as rotation and rotation shear are increased. However, the difference in the fusion performance parameter G ($=\beta_{\mathrm{N}} \cdot H/q^2$) at low and high rotation is only 10%-30%. Thus, although rotation and rotation shear are important parameters for improving tokamak performance, good confinement and stability can be maintained even in their absence.

[1]Supported by US DOE under DE-FC02-04ER54698.

4:00PM UI1.00005 MHD simulations of disruption mitigation on DIII-D and Alcator C-Mod[1]

, V.A. IZZO, University of California, San Diego — The three potential threats posed by disruptions—halo currents, heat fluxes and runaway electrons—scale unfavorably from present tokamaks to ITER. Disruption mitigation experiments on several tokamaks have shown massive gas injection (MGI) to be an effective means of reducing poloidal halo current and heat flux. However, both theory and measurements support the conclusion the penetration of the neutral jet is weak. Thus the core thermal quench relies on MHD, both to mix impurities into the core, and to conduct heat to the impurity-dense edge. NIMROD simulations of C-Mod have shown that enhanced transport alone—due to large 1/1 and 2/1 modes triggered by edge cooling—can quench the core plasma [1]. These simulations show similarity to C-Mod temperature measurements [2], and the role of the 1/1 and 2/1 modes is supported by observations in DIII-D [3]. However, to determine the relative importance of thermal transport versus impurity mixing simulations that include both mechanisms are needed. An extension of the NIMROD code has been developed which includes both accurate atomic physics from the 0D KPRAD code and separate continuity equations for each species. C-Mod simulations for both helium and argon impurities are compared with earlier simulations and experimental data to assess the extent of impurity mixing and evaluate MGI as a mitigation technique for ITER. DIII-D simulations are carried out with different radial neutral fueling profiles to understand the thermal quench when impurity injection is more uniform, or centrally peaked, as would be the case for designer pellets or liquid jets.

[1] V.A. Izzo, Nucl. Fusion **46** (2006) 541.
[2] R.S. Granetz, et al., Nucl. Fusion **46** (2006) 1001.
[3] E.M. Hollmann, et al., Nucl. Fusion **45** (2005) 1046.

[1]Supported by US DOE under DE-FG03-95ER54309; In collaboration with D.G. Whyte, P.B. Parks, E.M. Hollmann, R.S. Granetz.

4:30PM UI1.00006 Momentum transport from current-driven reconnection , FATIMA EBRAHIMI, University of Wisconsin and Center for Magnetic Self-Organization in Lab and Astrophysical Plasmas — In rotating toroidal plasmas in both laboratory and astrophysical settings, toroidal angular momentum is observed to be transported radially outward. In both cases the transport is much greater than can be explained by collisional viscosity. In the reversed field pinch (RFP), the toroidal rotation profile flattens abruptly during a reconnection event. To explain the RFP transport, we have performed a theoretical and computational study of momentum transport from reconnection - from tearing modes in the presence of sheared flow. We find that, whereas a single mode produces transport, a strong enhancement in transport arises from the nonlinear coupling of multiple modes. A single tearing mode, in the presence of equilibrium flow, produces momentum transport in the vicinity of the reconnection layer. This is demonstrated from quasilinear calculation of Maxwell and Reynolds stresses. However, nonlinear, resistive MHD computation of the full, multi-mode dynamics reveals an additional effect. In the presence of multiple tearing modes, nonlinear coupling strongly enhances the torques. The effect of multiple tearing modes is not merely the superposition of independent, radially separated effects. Rather, the torque from one spatial mode is itself increased by the presence of other modes. The resulting transport is much more rapid than that from viscosity only. Theoretical results will be compared to momentum transport measurements in the MST experiment. Momentum transport in astrophysical plasmas (such as accretion disks) is generally thought to arise from flow-driven MHD instability. Our work raises the question of whether current-driven instability can play a role. Preliminary application to astrophysical disks will be discussed. Work supported by NSF and DOE.

Thursday, November 15, 2007 2:00PM - 3:00PM –
Session UT2 Tutorial: Hydromagnetic Dynamos Rosen Centre Hotel Salon 3/4

2:00PM UT2.00001 New directions in the theory of hydromagnetic dynamos[1] , FAUSTO CATTANEO, University of Chicago/ Argonne National Laboratory — In dynamo theory a distinction is made between small- and large-scale dynamo action. The former refers to the generation of magnetic fields on scales smaller than or comparable with the characteristic scale of the velocity. It is now widely believed that in a turbulent fluid, small-scale dynamo action is always possible provided the magnetic Reynolds number is sufficiently high. Large-scale dynamo action, on the other hand, refers to the generation of large-scale fields, i.e the generation of magnetic flux which is of considerable importance in many astrophysical situations. The traditional view is that large-scale generation occurs via an inverse cascade of magnetic helicity driven by turbulence lacking reflectional symmetry. This view, however, is becoming increasingly at odds with numerical simulations that show that the cascade is either absent or ineffective. The question then arises of what are the alternative mechanisms that can leads to the generation of large-scale fields. I will discuss two possible resolutions: one based on the role of boundary conditions in releasing the constraints of helicity conservation, the other based on the existence of special classes of velocity fields that are generated by magnetic instabilities and that are particularly suited to dynamo action. In both cases I will discuss important analogies between the astrophysical and the laboratory situations.

[1]This work was supported byt the NSF sponsored Center for Magnetic Self-Organization

Thursday, November 15, 2007 2:00PM - 5:00PM –
Session UO3 Hohlraum Physics I Rosen Centre Hotel Salon 9/10

2:00PM UO3.00001 Optimizing the NIF Ignition Hohlraum[1] , DEBRA CALLAHAN, DENISE HINKEL, LAURENT DIVOL, STEVE HAAN, OGDEN JONES, BRUCE LANGDON, PIERRE MICHEL, LARRY SUTER, RICHARD TOWN, ED WILLIAMS, LLNL — In order to optimize the hohlraum for ignition on the National Ignition Facility laser, we need to consider a variety of aspects of the system: laser plasma interactions (LPI), hohlraum energetics, capsule performance, hohlraum asymmetry, laser performance, and target fabrication. In preparation for the first ignition campaign, we have designed a suite of ignition hohlraums that span the range of temperatures consistent with initial NIF operations: 300 eV, 285 eV, and 270 eV. Experiments with 96 beams that are designed to emulate these ignition designs, coupled with flexible target fabrication and laser phase plate production, will allow us to use experiments to guide our choice of the optimal hohlraum for ignition. In this talk, we will describe the suite of ignition designs under consideration, and discuss the trade-offs between the different parts of the system for each design.

[1]Work performed under the auspices of the U.S. DOE by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

2:12PM UO3.00002 Scaling and modeling of x-ray preheat in laser heated hohlraums , L. SUTER, O. LANDEN, E. DEWALD, J. SCHEIN, M. ROSEN, Lawrence Livermore National Laboratory — X-rays with photon energy >1.5keV can preheat the inside of the ablator of an indirect drive ignition capsule. Since the amount of inner ablator preheat affects the hydrodynamic stability of the ablator-DT ice interface, ignition capsules include mid-Z dopants such as Cu or Ge in their ablators to control the inner surface preheat. The amount of dopant depends on the level of x-ray preheat in the hohlraum. In this talk we present measurements of x-ray preheat levels from hohlraum experiments performed with a single quad of NIF (NEL). We show the scaling of x-ray preheat with intensity and with radiation temperature and compare that to predictions made with Lasnex. Finally, we discuss how this affects our expectations for preheat in upcoming NIF ignition hohlraums. This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

2:24PM UO3.00003 X-ray induced preheat in indirect drive candidate ablators for the NIF , SHON T. PRISBREY, DAVID K. BRADLEY, DAVID G. BRAUN, OTTO L. LANDEN, JON H. EGGERT, Lawrence Livermore National Laboratory — We have developed a hohlraum platform to experimentally measure preheat in materials during the first 1-2 nanoseconds of the current Haan pulse for ignition on the National Ignition Facility. The platform design approximates the radiation environment of the pole of the capsule by matching the laser spot intensity and illuminated hohlraum wall fraction. VISAR reflecting off the back of the sample was used to measure sample motion prior to shock breakout. We will present our experimental results and simulations for candidate ablator samples. Both experiment and simulation results indicate that the ablator materials remain far from melt or the coexistence region which satisfies the NIF ignition requirement. This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48. UCRL-ABS-232885.

2:36PM UO3.00004 Using view factor analysis to understand symmetry for NIF Indirect Drive[1] , CLIFF THOMAS, MICHAEL EDWARDS, Lawrence Livermore National Lab — To achieve ignition, a NIF capsule requires a high degree of drive symmetry. In practice, this is obtained with the careful balance of several parameters (such as the number of laser cones, and/or the distribution of laser power between separate laser cones). Since the available parameter space is large, it can be difficult to optimize the symmetry using full-physics models. To motivate the further investigation of the available parameter space, and to provide greater insight on symmetry, this study considers a view factor description of radiation transport for indirect drive. Using this approach, the flux on the capsule can be understood as a function of laser pointing, laser spot size, cone balance, and hohlraum geometry (hohlraum length, capsule radius, and LEH size). As a result, avenues for tuning symmetry are explained, and suggestions are made to improve symmetry through the full laser drive.

[1]This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

2:48PM UO3.00005 Simulation studies of the re-emit technique for foot tuning of the NIF ignition pulse[1] , JOSE MILOVICH, EDWARD DEWALD, JOHN EDWARDS, DON MEEKER, LLNL — The re-emit technique has been proposed to tune the drive flux asymmetry within the first 2 ns of the ignition pulse. This technique measures the soft x-ray emission of a high-Z sphere (in place of a NIF capsule) using several frequency bands. We present numerical results designed to validate this method. Capsule-only simulations show a linear relationship between imposed and re-emitted flux asymmetry. 2D hohlraum simulations show similar plasma conditions for both ignition and re-emit capsules up to $\sim$4 ns. However, simulations predict that an inner-beam-driven heat conduction wave impacts the re-emit sphere limiting the applicability of this technique beyond 2 ns. The effect of diagnostic holes and beam removal is assessed by performing 3D simulations. They show a 4% offset in the measured asymmetry, largely time independent and consistent with view-factor calculations. These results combined with the experimental accuracy estimates, show that the re-emit is effective for tuning the first $\sim$2ns of the ignition pulse.

[1]Work performed under the auspices of US DOE by the UC LLNL under Contract No. W-7405-Eng-48.

3:00PM UO3.00006 Development of the re-emit technique for ICF foot symmetry tuning for indirect drive ignition on NIF[1] , EDUARD DEWALD, JOSE MILOVICH, JOHN EDWARDS, CLIFF THOMAS, DAN KALANTAR, DON MEEKER, OGDEN JONES, LLNS — Tuning of the the symmetry of the hohlraum radiation drive for the first 2 ns of the ICF pulse on NIF will be assessed by the re-emit technique [1] which measures the instantaneous x-ray drive asymmetry based on soft x-ray imaging of the re-emission of a high-Z sphere surrogate capsule. We will discuss the design of re-emit foot symmetry tuning measurements planned on NIF and their surrogacy for ignition experiments, including assessing the residual radiation asymmetry of the patches required for soft x-ray imaging. We will present the tuning strategy and expected accuracies based on calculations, analytical estimates and first results from scaled experiments performed at the Omega laser facility.
[1] N. Delamater, G. Magelssen, A. Hauer, Phys. Rev. E 53, 5241 (1996.)

[1]This work was performed under the auspices of the U.S. DOE by UC LLNL under Contract W-7405-Eng-48.

3:12PM UO3.00007 Using backlit thin shell capsules to tune drive symmetry during ignition implosions. , JOHN EDWARDS, R. KIRKWOOD, E. DEWALD, D. MEEKER, J. MILOVICH, D. KALANTAR, O. LANDEN, LLNL, R. GOLDMAN, M. SCHMITT, LANL, B. AFEYAN, Polymath — In order to attain ignition in cryogenic implosions on the NIF it is necessary for the assembling hot spot to be highly symmetric. To achieve this the drive must be carefully managed to integrate out to less than $\sim$ 1%, avoiding symmetry swings larger than $\sim$ few %. Drive symmetry swings typically occur during rapid changes in the laser pulse due to albedo changes but also as a result of laser spot motion. The swings can be controlled by the relative powers in the inner and outer laser cones as a function of time. Thin, light shells respond rapidly to drive asymmetries, which can then be detected in radiographs of the shells at some later times. Here we describe how this technique can be used to tune drive symmetry in the early parts of an ignition laser pulse. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. UCRL-ABS- 232769

3:24PM UO3.00008 Implosion of Large Scale, Be, Thin Shell Capsules on Omega, Under NIC Conditions[1] , R.K. KIRKWOOD, E. DEWALD, D. MEEKER, J. MILOVICH, D.H. KALANTAR, O.L. LANDEN, LLNL, S.R. GOLDMAN, M. SCHMITT, LANL, B.B. AFEYAN, Polymath — One technique to obtain symmetric ignition implosions on NIF is to measure the symmetry of the hohlraum radiation drive as a function of time by monitoring the shape of the imploded capsules by x-ray backlit imaging. To enhance the sensitivity of this measurement to time-dependent asymmetries, different thickness surrogate capsules will be used. Backlit images of thin (13 to 27 μm) Cu doped Be shells are planned during the foot of the ignition pulse between 2.0 and 10.2 ns. Recent experiments at the Omega laser facility provided images of 0.7-scale Be capsules doped with 2% Cu under NIC foot conditions. Images of the imploding shell were recorded with a 4.7 keV (Ti), folded foil backlighter between 6.0 and 7.7 ns. These images showed an absorption limb shape, with minimum transmission and radius that closely match the design values, indicating the integrity and response of the imploding shell up to the measurements times. Capsule and drive symmetry, and the quality of the images and comparison with predicted signal and noise models will be discussed.

[1]This Work was performed under the auspices of the U.S. DOE by UC LLNL under contract No. W-7405-ENG-48.

3:36PM UO3.00009 Design of Symmetry Capsules for the National Ignition Facility[1] , S.V. WEBER, N. IZUMI, M.J. EDWARDS, D.H. KALANTAR, LLNL, N.M. HOFFMAN, D.C. WILSON, LANL — Symmetry capsules (SymCaps) will be used to tune the symmetry of the hohlraum x-ray drive for the National Ignition Facility (NIF). Stringent symmetry requirements are specified for the drive from each of four steps of the laser pulse powering the NIF indirect drive ignition capsule. SymCaps are gas-filled surrogates used to tune the high-power 4th step of the pulse. The first three pulse steps will be tuned in earlier experiments. X-ray emission from the capsule core near peak compression will be observed with a gated x-ray imager. Round images, indicating symmetric drive, may be achieved by adjusting the hohlraum length, beam pointing, and power ratio of the laser beam cones. The full thickness SymCap design replaces the frozen DT layer of the ignition capsule with equivalent $\rho\Delta R$ of Be. This SymCap is predictive of the core shape at ignition of the cryogenic capsule. Time-dependent drive symmetry will be optimized using thinner SymCaps having temporal sensitivity weighted earlier. We will present a simulated tuning campaign and demonstrate that SymCaps facilitate achieving adequate symmetry to drive the cryogenic capsule to ignition.

[1]This work was performed under the auspices of the U.S. DOE by the Univ. of California, LLNL under contract No. W-7405-Eng-48.

3:48PM UO3.00010 Symergy Designs for 96 Beam Full-pulse Pre-Ignition Hohlraums[1] , S. ROBERT GOLDMAN, P.A. BRADLEY, E.S. DODD, N.M. HOFFMAN, D.C. WILSON, Los Alamos National Laboratory — A major thrust in the development of 192 beam, 4 cone-angle hohlraums for NIF is the measurement, prediction, and tuning of drive symmetry with 96 beam, 2 cone-angle hohlraums within the next year, as well as the diagnosis of laser plasma interaction (LPI) conditions. Hohlraum designs to emulate relevant LPI behavior are currently available[2] and are being extended for scaled versions of 270 to 300 eV radiation temperature drives. We will present simulations with variable cone pointing and beam phasing for symmetry capsules in these configurations. The experiments we are designing will be crucial for demonstrating that we can measure, predict, and tune hohlraum drive symmetry in the presence of LPI under expected NIF conditions. The results should be useful for correlating the symmetry and timing of capsule implosions with laser beam propagation in the two cones.

[1]Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.
[2] NB Meezan (private communication)

4:00PM UO3.00011 Calculations for Omega symmetry capsule implosion experiments in ∼0.2 NIF scale high temperature hohlraums , N.D. DELAMATER, D.C. WILSON, G.A. KYRALA, E.S. DODD, A. SEIFTER, N.M. HOFFMAN, D.W. SCHMIDT, Los Alamos National Laboratory, V. GLEBOV, C. STOECKL, Laboratory for Laser Energetics, C.K. LI, J.A. FRENJE, M.I.T. — Symmetry capsules are planned to be used as a diagnostic of implosion symmetry at varying times during the NIF drive. A suitably designed symmetry capsule samples the drive symmetry up to the implosion "commit" time of the capsule, which varies for symmetry capsules of different shell thickness. Our capsules use Ge-doped plastic shells with shell thickness varying from 25 μm to 55 μm. We present calculations for Omega experiments using symmetry capsule implosions in gold hohlraums 1900 μm x 1200 μm, and 70 % laser entrance hole, which is approximately a 0.2 NIF scale ignition hohlraum and reaches temperatures of 265-275 eV similar to those during the NIF drive. These capsules may be used as a diagnostic of shell ρr, since the gas fill is d-He3 at 36 atm. The protons produced in the implosion escape through the shell and produce a proton spectrum, which is measured using wedge range filters. The neutron, proton yield and spectra change with capsule shell thickness as the un-ablated mass or remaining capsule ρr changes. This technique to measure capsule un-ablated mass will be applied to future NIF experiments with ignition scale capsules. Support by US DOE/NNSA, LANS LLC, Contract DE-AC52-06NA253.

4:12PM UO3.00012 Using beam phasing and pointing to control indirect drive implosion symmetry[1] , G. KYRALA, A. SEIFTER, N. HOFFMAN, D. WILSON, S.R. GOLDMAN, N. DELAMATER, Los Alamos National Lab, F.J. MARSHALL, V. YU GLEBOV, C. STOECKL, LLE Univ Rochester, J. FRENJE, C. LI, MIT — Implosions using inertial confinement fusion must be symmetric to achieve ignition on the NIF. This requires precise control of the drive symmetry incident on the ignition capsule. We performed two studies, using either beam pointing, or power imbalance [phasing] of three cones from the OMEGA laser to affect the symmetry of an imploded capsule. For pointing we used a NIF 0.7 scale vacuum-hohlraum and D_2-filled 1400 μm CH capsules to verify the technique. We captured images at different times for different pointings of the inner and middle laser cones, verifying the technique and demonstrating symmetry tuning. For phasing, a 1/4 scale NIF vacuum-hohlraum was used to drive a 475 μm diameter $D_2-{}^3$He-filled capsule. Imaging of the imploded core was used to measure the implosion symmetry and to verify its control. We also show that propagation of the inner beam cone is important, even in a vacuum hohlraum, and has the largest effect on the hohlraum energetics.

[1]Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

4:24PM UO3.00013 Demonstrating Control of Symmetry Capsule Implosions in Omega Experiments using NIF 0.7-Scale Hohlraums[1] , NELSON HOFFMAN, ROBERT GOLDMAN, GEORGE KYRALA, ACHIM SEIFTER, LANL — We have demonstrated the ability to detect the weak x-ray emission from, and control the imploded core shape of, large weakly-driven plastic capsules in NIF 0.7-scale hohlraums at the Omega laser. The capsules are similar to those that can be used to diagnose hohlraum radiation drive symmetry during the early stages ("foot") of the drive in eventual NIF ignition experiments. Because the foot drive temperature is so low (∼90 eV), it had been doubtful that capsule x-ray emission would be detectable. Because the capsule shells must be thin, making them hydrodynamically unstable and subject to complete ionization ("burnthrough") before peak compression, it had been doubtful that their shape would respond to variations in laser beam pointing. We have now put those doubts to rest. These experiments used 1400-μm diameter CH shells, of thickness 15-20 μm, filled with 1 atm D_2, in 6.38 mm x 3.56 mm gold hohlraums. No higher-Z dopant was necessary to make the x-ray emission detectable.

[1]Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

4:36PM UO3.00014 Using Symcaps as Ignition Capsule Replicas for Diagnosing Symmetry at NIF[1] , I.L. TREGILLIS, N.M. HOFFMAN, N.D. DELAMATER, Los Alamos National Laboratory — Achieving ignition at NIF will require a high degree of symmetry in the imploded capsule cores. Ignition capsule symmetry specifications are stated in terms of the hotspot shape. "Symcaps" (symmetry capsules), which can be used to replicate the ignition capsule during different stages of implosion, show promise in revealing the hotspot shape. Here we present an analysis of the correlation between ignition capsule and symcap core shapes under a wide variety of beam phasing conditions. Using image galleries and a metric developed for quantifying the correspondence between capsule shapes, we find that a well-designed symcap can mimic the response of an ignition capsule to beam phasing changes in highly symmetric and highly asymmetric situations. Symcaps are a viable method of predictiing the level of P_2 and P_4 asymmetry in an ignition capsule implosion. We will also describe an effort to optimize the correspondence by refining the symcap design.

[1] Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

4:48PM UO3.00015 Experimental demonstration of increased radiation temperature using foam-walled hohlraums , A.B. REIGHARD, P.E. YOUNG, M.D. ROSEN, J.H. HAMMER, W.S. HSING, S.G. GLENDINNING, R.E. TURNER, R. KIRKWOOD, J. SCHEIN, C. SORCE, J. SATCHER, A. HAMZA, G. NYCE, O. LANDEN, LLNL, S. MCALPIN, M. STEVENSON, B. THOMAS, AWE — Hohlraums are used in ICF applications to produce a nearly uniform x-ray radiation drive for imploding capsules. Primary x-rays produced by laser beams focused onto the inner wall are absorbed and re-radiated by the hohlraum interior. Analytic analysis and simulations have shown that there is an optimum hohlraum wall density which maximizes the temperature in the radiation heat wave and minimizes energy loss from hydrodynamics [1]. This has been demonstrated in experiments using cylindrical hohlraums, with either 100 mg/cc or 4 g/cc Ta_2O_5 inner walls. The low-density hohlraums had a maximum of 15% higher peak x-ray flux, and 5% higher radiation temperatures than 4 g/cc Ta_2O_5 targets in time-resolved Dante measurements. This work was performed under the auspices of the U.S. DOE by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48. [1] M. Rosen and J. Hammer, Phys. Rev. E., **72**, 056403 (2005).

Thursday, November 15, 2007 2:00PM - 4:24PM –

Session UO4 Laboratory Astrophysics Rosen Centre Hotel Salon 1/2

2:00PM UO4.00001 OMEGA Laser–Driven Hydrodynamic Plasma Jet Experiments with Relevance to Astrophysics , S.L. SUBLETT, J.P. KNAUER, D.D. MEYERHOFER, T.J.B. COLLINS, A. FRANK, Laboratory for Laser Energetics, U. of Rochester — Using the University of Rochester's OMEGA laser, experimental techniques have been developed to study plasma jets. A charge-coupled-device (CCD) detector was configured to measure the jet evolution with a high signal-to-noise ratio compared with previous film detectors. The evolution of experimental supersonic plasma jets was observed over many dynamical times. Double-pulsed jets looked similar to single-pulsed jets at times long compared to the pulse separation. The bow-shock profiles of the experimental jets matched the predictions of an astrophysical energy-driven jet model. These jet experiments extend the applicable regime of impulsive, energy-driven jet simulations to density contrasts greater than 1. The experimental jets were observed under controlled conditions during earlier stages of development than astrophysical jets can be observed. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement DE-FC52-92SF19460.

2:12PM UO4.00002 Laboratory Studies of High Mach Number Shock Collisions with Foils and Density Discontinuities. , MATTHIAS HOHENBERGER, R. CARLEY, J. LAZARUS, J. CHITTENDEN, R.A. SMITH, Imperial College, London — The dynamics of strong shocks, blast waves and radiative blast waves play a key role in astrophysical objects such as nebulae and supernova remnants. Our understanding of these complex systems is underpinned by numerical simulations, however despite decades of work modeling of such phenomena remains extremely challenging. The interaction of strong shocks with discontinuities and reflecting surfaces represents a particularly demanding scenario against which to test rad-hydrocodes. As a result we have been developing scaled laboratory experiments to provide high quality data for code benchmarking, and to aid our physical insight. We report on experimental and numerical investigations into the interaction of strong shocks and blast waves with solid obstructions and density discontinuities. Shocks were driven by focusing a high intensity 750fs laser into a near atmospheric density atomic cluster medium at 10E17 W/cm^2. Placing a solid foil in the gas stream used to create clusters produced a hydrodynamic bow shock, allowing us to investigate both shock-foil and shock-density discontinuity interactions. Shock evolution was followed as a function of time with an optical probe via Schlieren and interferometric imaging techniques. Numerical modeling of our experimental test system was carried out using the 3D magnetoresistive hydrocode GORGON.

2:24PM UO4.00003 3D Tomographic imaging of colliding cylindrical blast waves , R.A. SMITH, J. LAZARUS, M. HOHENBERGER , J. ROBINSON, A. MAROCCHINO, J. CHITTENDEN, M. DUNNE, A. MOORE, E. GUMBRELL, Imperial College, London. — The interaction of strong shocks & radiative blast waves is believed to give rise to the turbulent, knotted structures commonly observed in extended astrophysical objects. Modeling these systems is however extremely challenging due to the complex interplay between hydrodynamics, radiation and atomic physics. As a result we have been developing laboratory scale blast wave collision experiments to provide high quality data for code benchmarking, & to improve our physical understanding. We report on experimental & numerical investigations of the collision dynamics of counter propagating strong (>Mach 50) cylindrical thin-shelled blast waves driven by focusing intense laser pulses into an extended medium of atomic clusters. In our test system the blast wave collision creates strongly asymmetric electron density profiles, precluding the use of Abel inversion methods. In consequence we have employed a new tomographic imaging technique, allowing us to recover the full 3D, time framed electron density distribution. Tomography & streaked Schlieren imaging enabled tracking of radial & longitudinal mass flow & the investigation of Mach stem formation as pairs of blast waves collided. We have compared our experimental system to numerical simulations by the 3D magnetoresistive hydrocode GORGON.

2:36PM UO4.00004 Spike Extensions in Rayleigh-Taylor, Decelerating-Interface Experiments , C.C. KURANZ, R.P. DRAKE, University of Michigan, M.J. GROSSKOPF, H.F. ROBEY, J.F. HANSEN, A.R. MILES, J. KNAUER, T. PLEWA, N. HEARN — This presentation discusses experiments well-scaled to the blast wave driven explosion phase of SN1987A. These experiments, performed at the Omega Laser facility, use $\sim$ 5kJ of laser energy to create a blast wave similar to those in supernovae. The blast wave crosses a perturbed interface with a density drop and produces Rayleigh-Taylor instability (RTI) growth. By performing experiments with more complex, three-dimensional initial conditions, we hope to observe the effect their complexity has on RTI growth. Recent advancements in x-ray backlighting have greatly improved the resolution of our x-ray radiographic images. These images show some mass extending beyond the spike tips. This presentation will discuss the amount of mass in these spike extensions. This research was sponsored by the NNSA through DOE Research Grants DE-FG52-07NA28058, DE-FG52-04NA00064, and other grants and contracts.

2:48PM UO4.00005 Supersonic plasma jet interaction with gases and plasmas at the PALS laser facility , PH. NICOLAI, C. STENZ, X. RIBEYRE, V. TIKHONCHUK, CELIA, University Bordeaux, France, A. KASPERCZUK, T. PISARCZYK, IPPLM, Warsaw, Poland, L. JUHA, E. KROUSKY, K. MASEK, M. PFEIFER, K. ROHLENA, J. SKALA, IP, Prague, Czech Rep., J. ULLSCHMIED, IPP, Prague, Czech Rep., M. KALAL, D. KLIR, J. KRAVARIK, P. KUBES, CTU, Prague, Czech Rep., P. PISARCZYK, WUT, Warsaw, Poland — The interaction of supersonic plasma jets with dense gases and plasmas has been studied experimentally and theoretically. Under suitable conditions on the laser intensity, spot radius and target atomic number, a radiative jet can be launched from a simple planar target with a 100 J laser pulse [Ph. Nicolai et al, Phys. Plasmas 13, 062701 (2006)]. A typical copper jet has a velocity around 500 km/s, a Mach number greater than 10, a density around 10^{18} cm^{-3}, a length of a few millimeters and a radius of 0.5 mm. The interaction of such a jet with Ar and He gas puffs at different pressures has been studied by using various optical and x-ray diagnostics. Qualitative estimates and numerical simulations with a 2D radiation hydrodynamic code allow to explain a sequence of physical processes during the interaction, which include the collision of two plasmas, shock propagation and radiation cooling. Variations in the atomic number and pressure of a target plasma allow us to control the role of radiative and kinetic processes in the jet evolution.

3:00PM UO4.00006 Laser-triggered millimeter-scale collimated plasma jets in crossed electric and magnetic fields. , HERNAN QUEVEDO, PARRISH BRADY, PRASHANT VALANJU, MATT MCCORMACK, ROGER BENGTSON, TODD DITMIRE, University of Texas at Austin, Physics Department — Some physical aspects of astrophysical jets can be scaled to laboratory experiments using magneto hydrodynamic scaling laws. We present a laser plasma-triggered jet experiment where we produce a millimeter-scale collimated outflows from a cylindrically symmetric electrode configuration. The electrode design consists of a grounded plane with a $\sim$1 cm diameter hole and a wire aligned normally to this plane, with its tip placed at the center of the hole. A rapid discharge is formed between the wire and ground plane when a laser pulse hits an aluminum target placed above the electrodes, creating a plasma which closes the circuit. The resulting current and corresponding magnetic field give rise to a plasma jet. The jets were 0.1-0.3 cm wide, about 2 cm in length, had velocities of $\sim$20 km/s and an estimated plasma density of less than 10^{17} particles/cm^3. To study the effects of magnetic fields on jet evolution, we have embedded the plasma in axially directed permanent magnetic fields with strength up to 0.4 Tesla. We have measured the evolution of the jet over a duration of $\sim$1 μs with nanosecond resolution using a fast ICCD camera and interferometry. Under certain conditions the jets also form helical structures due to kink instabilities and the onset is characterized.

3:12PM UO4.00007 Experimental Study of Episodic Magnetically Driven Radiatively Cooled Plasma Jets , F. SUZUKI-VIDAL, S.V. LEBEDEV, S.N. BLAND, J.P. CHITTENDEN, G.N. HALL, A. HARVEY-THOMPSON, A. MAROCCHINO, Imperial College London, A. CIARDI, C. STEHLE, Observatoire de Paris, S.C. BOTT, University of California, San Diego, A. FRANK, E.G. BLACKMAN, University of Rochester, T. RAY, Dublin Institute for Advanced Studies — Previous experiments on the 1MA MAGPIE generator have successfully showed the formation of magnetically driven radiatively cooled plasma jets which are relevant to the launching of astrophysical jets. The jets in these experiments are driven by the pressure of the toroidal magnetic field produced by the current, which leads to the formation of a "magnetic tower" structure. This scenario is characterized by the formation of a magnetic "bubble" surrounding a collimated plasma jet on axis. A modification of this experimental configuration, in which radial wire array is replaced by radial metallic foil, results in the formation of episodic magnetic tower outflows which emerge periodically on timescales of $\sim$30ns. The subsequent magnetic bubbles propagate with higher velocities (increasing from $\sim$100km/s to $\sim$300km/s) and interacting with previous eruptions leading to the formation of shocks. This experimental setup also allows the study of the interaction of episodic outflows with an ambient medium. This research was supported by the EU JETSET network and the NNSA under DOE Cooperative Agreement DE-FC03-02NA00057.

3:24PM UO4.00008 Photon-photon scattering in vacuum and astophysical plasmas , G. BRODIN, Umea University — We present for the first time the nonlinear dynamics of quantum electrodynamic (QED) photon splitting in an electron-positron plasma that is held in a super-strong magnetic field. Such plasmas exist in magnetars, and may also arise in the next generation laser-plasma experiments. By using a QED corrected Maxwell equation, we derive a set of equations that show the existence of nonlinear couplings between electromagnetic (EM) waves due to nonlinear plasma currents and QED polarization and magnetization effects. Numerical analyses of our coupled nonlinear EM wave equations reveal the possibility of a new decay interaction, as well as new features of energy exchange among the three EM modes that are nonlinearly interacting in a magnetized pair plasma. Applications of our investigation to astrophysical settings, such as magnetars, are pointed out.

3:36PM UO4.00009 Line intensity enhancements in both stellar and laser-plasma coronal X-ray spectra due to opacity effects , JUSTIN WARK, University of Oxford, STEVEN ROSE, Imperial College, London, FRANCIS KEENAN, Queen's University Belfast, MICHAIL MATHIOUDAKIS, MARCO MATRANGA, Queen's University, Belfast — The intensity of optically thin transitions increase linearly with optical depth. As one might expect an optically thick line to increase less quickly than linearly, the thick to thin ratio is normally thought to decrease with increasing optical depth. However, for systems in coronal equilibrium, this is not necessarily the case, and this ratio can have enhancements that are a function of plasma geometry and viewing angle. Here we consider the X-ray spectra for a number of late-type active stars, obtained with the Reflection Grating Spectrometer on the XMM-Newton satellite. Both flare and quiescent spectra are considered, and intensity ratios studied which involve the Fe XVII 15.01 Å and 16.78 Å transitions. We consider a large dataset for a number of stars, and in particular the case of EV Lac, where the 15.01 Å line exhibits an enhancement in intensity over the optically thin value, which we interpret in terms of a geometry consistent with a largely planar feature on the surface of the star being observed at an angle of order 45 degrees. We show that such enhancements due to opacity should also be observable in laser-produced plasmas of specific geometry.

3:48PM UO4.00010 Iron plasma transmission measurements at temperatures above 150 eV , J.E. BAILEY, G.A. ROCHAU, P.W. LAKE, Sandia National Laboratories, C.A. IGLESIAS, Lawrence Livermore National Lab, J. ABDALLAH, JR., Los Alamos National Lab, J.J. MACFARLANE, I. GOLOVKIN, P. WANG, Prism Computational Science, R.C. MANCINI, U. of Nevada, Reno, C. BLANCARD, PH. CROSSE, G. FAUSSURIER, F. GILLERON, S. MAZEVET, J.C. PAIN, CEA, Bruyeres-le-Chatel, France, M. BUMP, O. GARCIA, T.C. MOORE, K-Tech — Measurements of iron plasma transmission at 156 $\pm$ 6 eV electron temperature and 6.9 $\pm$ 1.7 $\times 10^{21}$ cm^{-3} electron density are reported over the 800-1800 eV photon energy range. The temperature is more than twice that in prior experiments, permitting the first direct experimental tests of absorption features critical for understanding solar interior radiation transport. Detailed line-by-line opacity models are in excellent agreement with the data. Applications may require simplified models employing different approximations and the work described here provides a new ability to estimate the accuracy compromises that result. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Dept. of Energy under contract No. DE-AC04-94AL85000.

4:00PM UO4.00011 Radiative cooling in relativistic collisionless shocks. Can simulations and experiments probe relevant GRB physics?[1] , MIKHAIL MEDVEDEV, University of Kansas, ANATOLY SPITKOVSKY, Princeton University — We address the question of whether PIC simulations and laboratory laser-plasma experiments can (or will be able to, in a near future) model realistic gamma-ray burst (GRB) shocks. For this, we compare the radiative cooling time, $t_{\rm cool}$, of relativistic electrons in the shock magnetic fields to the microscopic dynamical time of collisionless relativistic shocks, ω_{pp}^{-1}. We have obtained that for $t_{\rm cool}\omega_{pp}^{-1} \lesssim$ few hundred, the electrons cool efficiently at or near the shock jump and are capable of emitting away a large fraction of the shock energy. Such shocks are well-resolved in the existing 2D PIC simulations, therefore the microscopic structure can be studied in details, whereas the spectral power of the emitted radiation can also be directly obtained from simulations and compared with observational data. The conditions in the GRB shocks are almost identical to those in laser-produced plasmas; thus, such GRB-like plasmas can be created and studied in laboratory experiments using the presently available Petawatt-scale laser facilities.

[1]Supported by DoE grants DE-FG02-04ER54790 and DE-FG02-07ER54940 and by NASA grant NNX07AJ50G.

4:12PM UO4.00012 Shock-processing of astrophysical dust grains[1] , J.F. HANSEN, G.A. GRAHAM, E.M. BRINGA, B.A. REMINGTON, LLNL, A.T. KEARSLEY, Natural History Museum, London, W. VAN BREUGEL, UC Merced, A.G.G.M. TIELENS, NASA Ames, E.A. TAYLOR, Open University, UK — We are developing a new capability to carry out experiments on the shock processing of astrophysical dust grains and cratering of space hardware due to hypervelocity interplanetary dust particle (IDP) impacts. A 527 nm, 200 J laser launches a shock through a target consisting of a 25 μm plastic ablator followed by a 200 μm, 100 mg/cm^3 foam. Dust grains embedded near the rear surface of the foam experience pressures of $\sim$200 kbar in a <50 ps spike, simulating astrophysical pressure conditions in grain-grain collisions. A first experiment shows acceleration of 5 μm diameter Al_2O_3 dust grains to several km/s as measured by particle image velocimetry using a double-pulsed probe laser that is Mie-scattered off the grains. The grains were allowed to impact high-purity Cu foils where they caused abundant cratering, similar to what is seen on recovered space hardware after exposure to IDPs. The cratering is currently being studied in scanning electron microscopes and a preliminary analysis will be presented.

[1]This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Thursday, November 15, 2007 2:00PM - 5:00PM –

Session UO6 Z Pinches and X Pinches Rosen Centre Hotel Salon 5/6

2:00PM UO6.00001 Perspectives on Recent Progress in Developing Ar K-shell Z-Pinch Sources[1] , J.P. APRUZESE, R.J. COMMISSO, B.V. WEBER, Plasma Physics Division, Naval Research Laboratory, D. MOSHER, F.C. YOUNG, L-3 Communications, Titan Group, Reston, VA, J.W. THORNHILL, J.L. GIULIANI, A.L. VELIKOVICH, J. DAVIS, Plasma Physics Division, Naval Research Laboratory, J.S. LEVINE, B.H. FAILOR, H. SZE, N. QI, J.W. BANNISTER, L-3 Communications, Pulse Sciences, P.L. COLEMAN, Alameda Applied Sciences Corporation, C.A. COVERDALE, Sandia National Laboratories — Various developments, including a three-plenum, "pusher-stabilizer-radiator" gas puff nozzle, have culminated in the doubling of achievable Ar K-shell yields on Sandia's Saturn generator, from 38 to 75 kJ. This was accomplished at comparatively long implosion times of $\sim$ 200 ns. This talk briefly reviews the more than 15 years of steady progress which brought this advance about. The Ar Z-pinches studied over that time have produced K-shell yields ranging from a few kJ on PITHON to $\sim$ 300 kJ on the Z generator. They have been analyzed with a consistent spectroscopic method in an effort to empirically ascertain what properties make such pinches good radiators. We also examine how much they depart from Bennett equilibrium.

[1]Work supported by the Defense Threat Reduction Agency and DOE/NNSA

2:12PM UO6.00002 The development of instabilities in wire array Z-pinches , JEREMY CHITTENDEN, Imperial College, CHRISTOPHER JENNINGS, Sandia National Laboratories — The X-ray power produced by wire array Z-pinches is ultimately limited by the uniformity and the characteristic width of the imploding plasma structure. This uniformity is in turn determined by spatial variations in the ablation rate of the individual wires earlier in time. These variations exhibit a fixed and highly periodic structure with a characteristic natural wavelength. The reasons for this fixed structure and the origin of such perturbations have been the subject of much debate in recent years. Using three-dimensional MHD calculations of a single wire in an array, we show that such variations can arise as the result of an m=0 like instability growing in the plasma ablating from each wire. The structure of this instability is modified by the magnetic topology of the array and is shown to grow spontaneously from noise to adopt a fixed wavelength which is consistent with experimental observations. Using separate three-dimensional MHD simulations of the entire array volume, we then show how the separate modulations from each wire combine to form a perturbation to the array implosion as a whole. The effect of the non-linear development of this perturbation on the X-ray power pulse is then illustrated. This work was partially supported by the U.S. Department of Energy through cooperative agreement DE-FC03-02NA00057.

2:24PM UO6.00003 Bounds for Kinetic Energy and Resistance for W wire array implosions on Z , EDUARDO WAISMAN, MICHAEL CUNEO, DANIEL SINARS, WILLIAM STYGAR, RAYMOND LEMKE, Sandia National Laboratories — Electrical and radiation data are analyzed for wire array z-pinches on the Z machine.The measured stack voltage and MITL current are employed to obtain the voltage at the Z vacuum convolute, and from it and the measured load current an upper bound for the wire array load inductance is constructed. Energy conservation is then employed to obtain the kinetic energy a few ns before stagnation, by observing that knowledge of the load inductance upper bound and the load current provide an upper bound for the magnetic energy downstream of the vacuum convolute, and that the internal energy is negligible at that time. An approximate lower bound for the pinch resistance is obtained at a time when the radiated X-ray power has decreased to a half of its peak value by assuming that at this point the pinch kinetic energy is negligible and by estimating the internal energy of the tungsten plasma from its apparent size and radiated power. Several single W wire array shots are analyzed using this technique. By further assuming that after the end of the ablation phase the pinch breaks up in two thin shells of prescribed mass their paths, as well as the current split between the two, are obtained self-consistently thereafter. Comparisons of the kinetic energy bound with results of 3D RMHD calculations for selected shots are provided. Insights gained by this data analysis are presented.

2:36PM UO6.00004 Faster, 80ns, current scaling experiments yield higher radiated x-ray power and approach quadratic dependence[1] , MICHAEL G. MAZARAKIS, MICHAEL E. CUNEO, WILLIAM A. STYGAR, HENRY C. HARJES, DANIEL B. SINARS, BRENT M. JONES, CHRISTOPHER DEENEY, EDUARDO M. WAISMAN, THOMAS J. NASH, KENNETH W. STRUVE, DILLON H. MCDANIEL, Sandia National Laboratories — We report the results of the latest series of current scaling experiments with the Z accelerator. The novelty of this work is the shorter implosion times of 80 ns as compared with the 95ns of the previously reported work. Our results show a radiated x-ray peak power and total radiated x-ray energy current scaling closer to quadratic than the results of Stygar *et al.* [Phys. Rev E **69**, 046403 (2004)]. If we include in the analysis all our thirteen shots, we find that the x-ray peak radiated power scales as the 1.57 power of the peak load current and the total x-ray radiated energy as the 1.9 power. However, we found that the power flow to the load during the shot 1608 was severely curtailed. If we eliminate that particular shot we find that the x-ray peak radiated power and total radiated energy scale respectively as 1.71 and 2.01 power. The present results are compared with the predictions of a heuristic and enhanced resistivity models.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

2:48PM UO6.00005 Measurement of Doppler implosion velocity in wire array z pinches[1] , B. JONES, J.E. BAILEY, G.A. ROCHAU, C.A. COVERDALE, M.E. CUNEO, Sandia National Laboratories, Y. MARON, V. FISHER, V. BERNSHTAM, A. STAROBINETS, Weizmann Institute, C. DEENEY, NNSA/DOE — Determination of z-pinch implosion velocity and thus coupled kinetic energy is key to understanding energy balance in wire array radiation sources. We discuss diagnosis of velocity via observation of Doppler shifts in K-shell lines for Al implosions on the 20 MA Z machine. For a small-mass load, classic oval-shaped Mg dopant lines are observed with a time- resolved, 1D-imaging (radial) spectrometer; Doppler splitting corresponding to $\sim$50 cm/μs is seen in the view through the pinch axis, while no splitting is seen in the view tangent to the imploding shell. Velocity can also be inferred from Doppler-shifted absorption lines observed in a large-mass wire array implosion when analyzed with a collisional-radiative and radiation transport model of a multi-shell plasma (emission from the hot core backlights the colder imploding mass).

[1]Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

3:00PM UO6.00006 Ablated Wire Material and Coronal Structure Interactions[1] , DAVID HAAS, University of California San Diego, SIMON BOTT TEAM, YOSSOF ESHAQ TEAM, UTAKO UEDA TEAM, FARHAT BEG TEAM — Results are presented from experiments studying the mass ablation, propagation, and jet development exhibited in pulsed power experiments. Jets were formed from x-pinches and low wire number conical wire arrays. They were observed to form between the electrodes and propagating above the anode. All results were obtained on a compact pulsar having a maximum current of 80 kA with a rise-time of 50ns. Optical probing diagnostics included side on interferometry, shadowgraphy, and schlieren imaging. Time gated x-ray images were recorded simultaneously to trace the emission profile. Several wire materials, including aluminum, tungsten, and stainless steel, were investigated to determine the effect of radiation cooling. Jet parameters such as velocity, density, and temperature were investigated, along with dimensionless parameters to assess scalability to astro-physical regimes. Laboratory scale plasma jet interaction with side winds will be attempted.

[1]This work supported by the DOE Junior Faculty Grant DE-FG02-05ER54842

3:12PM UO6.00007 The Implosion of Radial Wire Array Z-Pinches , S.N. BLAND, S.V. LEBEDEV, F. SUZUKI-VIDAL, J.P. CHITTENDEN, G.N. HALL, A. HARVEY-THOMPSON, J.B.A. PALMER, Imperial College London, D.J. AMPLEFORD, Sandia National Laboratories, K. CHANDLER-MITCHELL, M. MITCHELL, Idaho State University — Radial wires array z-pinches - where the wires stretch radially outwards from a central cathode - offer a number of advantages over cylindrical arrays. Imploding in a similar fashion to a dense plasma focus, plasma from a radial array is projected above the electrodes, allowing experimental access over an entire hemisphere. The implosion is also compact and so is suitable for coupling to small scale hohlraums. Additionally radial arrays can be matched to low impedance generators and may enable the use of long pulsed drive currents. Here we present measurements of the dynamics of radial wire array z-pinches, examining wire ablation, implosion and the dynamics of the stagnating column. The scaling of power and yield of soft and hard X-rays with array configuration is explored. The effect of placing the radial wire array within a hohlraum is examined, as are nesting techniques both for increasing wire number and symmetry and for Xray pulse shaping. This research was supported by the NNSA under DOE Cooperative Agreement DEFC03 - 02NA00057

3:24PM UO6.00008 The Structure of Ablated Plasma from Coiled Wire Arrays , G.N. HALL, S.N. BLAND, S.V. LEBEDEV, J.P. CHITTENDEN, J.B.A. PALMER, F.A. SUZUKI-VIDAL, Imperial College London, S.C. BOTT, University of California, San Diego — Coiled arrays, a cylindrical array in which each wire is formed into a helix, suppress the modulation of ablation at the fundamental wavelength. Outside the vicinity of the wire cores, ablation flow from coiled arrays is modulated at the coil wavelength and has a 2- stream structure in the r,? plane. Within the vicinity of the helical wires, ablation is concentrated at positions with the greatest azimuthal displacement and plasma is axially transported from these positions such that the streams become aligned with sections of the coil furthest from the array axis. The GORGON MHD code accurately reproduces this observed ablation structure, which can be understood in terms of axial JxB forces that result from the interaction of the global magnetic field with radial components of a helical current path as well as additional current paths suggested by the simulations. These experiments were performed on MAGPIE (1MA, 240ns) at Imperial College. This research was sponsored by Sandia National Laboratories Albuquerque, the SSAA program of NNSA under DOE Cooperative Agreement DE-FC03-02NA00057.

3:36PM UO6.00009 Ablation of wires in an inverse wire array z-pinch[1] , SERGEY LEBEDEV, G.N. HALL, S.N. BLAND, F.A. SUZUKI-VIDAL, J.P. CHITTENDEN, Imperial College London, C. JENNINGS, SNL, A. HARVEY-THOMPSON, CHENG NING, Imperial College London, J.B.A. PALMER, AWE Aldermaston — We describe experiments on the MAGPIE facility (1MA, 250ns) with inverse wire array z-pinches, in which the wires act as a return current cage placed around a central current conductor. In this configuration the plasma ablated from the wires is pushed by the JxB force in the radially outward direction and expands into the region free of the magnetic field. This allows quantitative characterisation of the plasma ablated from an individual wire using laser interferometry, X-ray radiography and XUV imaging. The inverse z-pinch configuration also allows to measure separately the contribution to the inductance coming from the "private" magnetic flux of the wires and thus to evaluate the size of the current-carrying region around the wire cores. Quantitative information obtained in these experiments will be compared with results of 3-D MHD computer simulations.

[1]This research was sponsored by the NNSA under DOE Cooperative Agreement DE-FC03-02NA00057

3:48PM UO6.00010 Investigation of implosions in star-like wire arrays on the 1-MA Zebra generator , V.V. IVANOV, V.I. SOTNIKOV, A. HABOUB, A.L. ASTANOVITSKIY, A. MOROZOV, S.D. ALTEMARA, C. THOMAS, S. BATIE, V. NALAJALA, University of Nevada, Reno, A.P. SHEVELKO, E.D. KAZAKOV, P.N. Lebedev Physical Institute, Moscow — Implosions in star-like wire arrays, consisting of multiple rays of linear wire rows extending from the central axis, were investigated in the 1-MA Zebra generator. Arrays with 12-24 wires placed on 3-8 rays and 3-6 cylinders were tested. In star-like arrays the imploding plasma cascades to the center from wire to wire along rays of the star and forms plasma columns with a smooth leading edge. Shadowgraphy shows improved plasma homogeneity and mitigation of instabilities. Despite the low azimuthal symmetry, star-like wire arrays produce a stable x-ray pulse with the enhanced peak power of 0.4 TW and the shortest duration of 8-12-ns among other loads in this series of shots. Dynamics of the implosion in star-like wire arrays are compared with cylindrical and nested arrays. Work was supported by the DOE/NNSA under UNR grant DE-FC52-06NA27616.

4:00PM UO6.00011 Analysis of implosion and spectroscopic characteristics of combined planar wire arrays composed from low- and mid-z wire materials on the 1MA pulsed power generator at UNR , A.S. SAFRONOVA, V.L. KANTSYREV, N.D. OUART, M.F. YILMAZ, K. WILLIAMSON, V. SHLYAPTSEVA, I. SHRESTHA, G. OSBORNE, University of Nevada, Reno, C.A. COVERDALE, Sandia National Laboratories, C. DEENEY, NNSA, DOE — Analysis of single combined planar wire array experiments is presented. In these experiments, which were conducted at the 1 MA pulsed power generator at UNR, the Z-pinch load consisted of two Al and several Cu alloyed wires mounted in a single linear row with a 1 mm gap. Two wires of the primary Cu material were replaced by Al wires with the similar mass at three different locations. Implosion and radiative characteristics of such arrays were studied in connection with the particular location of two Al wires using filtered PCD and XRD detectors, a bare bolometer, time-gated and time-integrated pinhole cameras, and time-integrated, spatially resolved and time-gated spatially-integrated spectrometers. Non-LTE kinetic models were used to provide plasma parameters and to estimate opacity effects. This work was supported by NNSA under DOE Coop. Agr. DE-FC52-06NA27588, DE-FC52-06NA27586, and in part by DE-FC52-06NA27616. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States department of Energy under Contract DE-AC04-94AL85000.

4:12PM UO6.00012 Implosion dynamics and radiation features of planar, compact cylindrical, and nested wire arrays on 1 MA, 100 ns z-pinch generators , V.L. KANTSYREV, A.S. SAFRONOVA, A.A. ESAULOV, K. WILLIAMSON, I. SHRESTHA, G. OSBORNE, N.D. OUART, M.F. YILMAZ, V. SHLYAPTSEVA, University of Nevada, Reno, J.B. GREENLY, J.D. DOUGLASS, R.D. MCBRIDE, D.A. CHALENSKI, D.A. HAMMER, B.R. KUSSE, Cornell University, L.I. RUDAKOV, Icarus Res. Inc., A.S. CHUVATIN, Ecole Polytechnique — Plasma formation and implosion features of planar wire arrays (PWA), compact cylindrical wire arrays (CWA), and low-wire number nested wire arrays (NWA) of the small size (6-15 mm) were studied on the 1 MA, 100 ns UNR Zebra and Cornell COBRA generators. The powers and yields were maximum for Mo double PWA, followed by W compact CWA and PWA, Mo single PWA and compact CWA, stainless steel (SS304) and Al compact CWAs, and Al/SS304 and SS304/SS304 NWAs. Despite different implosion dynamics of PWAs and compact CWAs they formed plasma that radiated similar yields and powers. The possibility of radiation pulse shaping by varying geometry and materials of PWAs and NWAs will be discussed. Simulations with Wire Dynamics Model and 2D MHD model with enhanced resistivity will be presented. Work was supported by DOE/NNSA under Coop. Agr. DE-FC52-06NA27586, DE-FC52-06NA27588, DE-F03-02NA00057, and in part by DE-FC52 06NA27616.

4:24PM UO6.00013 Plasma Density Measurements within Tungsten Wire-Array Z-Pinches on the COBRA Accelerator[1] , JON DOUGLASS, RYAN MCBRIDE, KATE BELL, PATRICK KNAPP, JOHN GREENLY, SERGEI PIKUZ, TANYA SHELKOVENKO, DAVID HAMMER, Cornell University — The COBRA pulsed-power generator, with a nominal peak current of 1.1 MA and a minimum zero-to-peak rise-time of about 100ns, is being used to study the early phases of wire-array z-pinch development with a variety of diagnostics. Here we present the results of applying point-projection x-ray radiography to make accurate, high-resolution spatial and temporal measurements of the plasma density distributions in tungsten (W) wire-array z-pinch implosions. Density measurements are quantified by comparing x-ray transmission recorded on photographic films to transmission through W calibration steps of known thicknesses. Plasma density distributions as a function of time are presented for the coronal (10^{18}-10^{20}/cm^3), ablation ($<10^{18}$/cm^3) and on-axis ($<10^{19}$/cm^3) plasmas during the pre-stagnation phases of z-pinch dynamics (70-170 ns after the start of the current pulse). With this data set the time dependence of ablation velocity and corresponding mass ablation rate are addressed.

[1]This research was supported by the Stewardship Sciences Academic Alliances program of the National Nuclear Security Administration under DOE Cooperative agreement DE-FC03-02NA00057.

4:36PM UO6.00014 Implosion dynamics of wire-array z-pinches on the COBRA accelerator[1] , R.D. MCBRIDE, K.S. BELL, I.C. BLESENER, D.A. CHALENSKI, J.D. DOUGLASS, J.B. GREENLY, P.F. KNAPP, S.A. PIKUZ, T.A. SHELKOVENKO, T. BLANCHARD, H. WILHELM, D.A. HAMMER, B.R. KUSSE, Laboratory of Plasma Studies, Cornell University — Experimental results characterizing wire-array z-pinch implosion dynamics on the 1-MA, 100-ns rise time COBRA pulsed power generator are presented. Diagnostics fielded include an optical streak camera, a time-gated XUV framing camera, a laser shadowgraph system, filtered time-integrated pinhole cameras, a focusing x-ray spectrometer with spatial resolution (FSSR), a load voltage monitor, a faraday cup, a bolometer, silicon diodes and diamond photoconducting detectors (PCDs). The load geometries investigated in this set of experiments include cylindrical arrays ranging from 6 to 16 mm in diameter, and consisting of 8, 16, or 32 wires of either aluminum (Al) or tungsten (W). The data produced by the entire suite of diagnostics are analyzed and presented to provide an overall picture of implosion dynamics and timing on COBRA. In particular, data fitting to various implosion trajectory models, as well as x-ray pulse shape dependencies on various loads and implosion characteristics are presented and discussed.

[1]Research supported by NNSA Stockpile Stewardship Academic Alliances program under DOE cooperative agreement DE-FC03-02NA00057.

4:48PM UO6.00015 Soldered contact effect on wire array Z-pinches[1] , DAVID CHALENSKI, BRUCE KUSSE, JOHN GREENLY, Cornell University Laboratory of Plasma Studies — The Cornell University COBRA pulser is a nominal 1MA machine, capable of driving up to 16 wire cylindrical Z-pinch arrays. COBRA can operate with variable current risetimes ranging from 100ns to 250ns. Wires are typically strung with a "press" contact to the electrode hardware, where the wire is loosely pulled against the hardware and held there to form an electrical contact. Previous research with single wires on a 1-5kA pulser has shown that soldering the wire, thereby improving the wire/electrode contact, can improve the expansion of and energy deposition into the wire. Previous experiments on Z (T.W.L. Sanford et al., Phys. Plasmas 12, 122701 (2005)) have shown that improving the contact improves the X-ray yield. Data were collected on 16- and 8-wire, Aluminum, Copper and Tungsten Z-pinch arrays, with radii ranging from 16mm to 8mm. Experiments were conducted with both slow and fast risetimes (100ns and 200ns). The initiation, ablation, implosion and stagnation phases were compared for soldered and unsoldered arrays. Soldering appeared to produce a smaller radius pinch and improve X-ray yield in properly massed arrays.

[1]This research was supported by DOE grant DE-FG03-98ER54496, by Sandia National Laboratories contract AO258, and by the NNSA SSAA program under DOE Cooperative Agreement DE-FC03-02NA00057.

2:00PM - 2:00PM –

Session UP8 Poster Session VIII: Gyrokinetics, Two-Fluids and Assorted; DIII-D II; Turbulence and Transport; Plasma Sources, Sheaths, and Thrusters Rosen Centre Hotel Grand Ballroom, 2:00pm - 5:00pm

UP8.00001 GYROKINETICS, TWO-FLUIDS AND ASSORTED –

UP8.00002 An electrostatic, gyrokinetic-like model for thin layers with large gradients and electrostatic potentials , HAROLD WEITZNER, CHOONG-SEOCK CHANG, New York University, FRANK JENKO, Max-Planck Institute for Plasma Physics — Plasma dynamics is studied in a layer whose thickness is of the order of the geometric mean of the ion Larmor radius and the macroscopic scale length. The particle distribution functions and electric and magnetic fields all have the given gradient length. The motion of a single particle in such a state is treated. A magnetic moment adiabatic invariant exists and drift Hamiltonians are constructed. Kinetic equations are then developed, and have some properties of gyrokinetic equations. Charge neutrality, used to determine the electrostatic potential, is replaced by an equivalent condition, with explicit appearance of the potential. The linear stability of a straight, screw pinch is examined. Both stable and unstable special cases are found. Some results recover ion temperature gradient-like modes. However, large magnetic shear improves stability.

UP8.00003 The Solution of Boundary Layer Problems using Kruskal-Newton diagrams[1] , ROSCOE WHITE, Princeton University, THOMAS FISCHALECK, Institute fur Theoretische Physik, Magdeburg — The use of Kruskal-Newton diagrams for the solution of differential equations is illustrated with examples from the physics of pattern formation and plasma physics. The scaling of boundary layers is rapidly determined, and a systematic means of simplifying the internal layer equations is obtained.

[1]Supported bu US DoE

UP8.00004 Power-law statistics in beam-driven plasma-wave system with fluctuations: a signature of self-organized criticality, or something else?[1] , YU. TYSHETSKIY, J.A. ROBERTS, P.A. ROBINSON, I.H. CAIRNS, B. LI, University of Sydney — Numerical simulations of reduced-parameter model [1] of stochastic growth theory (SGT) [2] describing beam-driven plasma-wave systems with parameter fluctuations, display power-law tails in wave energy distribution function P(W) for certain parameters of the model. The characteristic spatiotemporal linear correlation scales of the system quantities [3], estimated at these parameters, are large compared to both the correlation scales of fluctuations driving the system, and to the system size, possibly indicating criticality occurring in the system. We study whether these power-law tails and diverging correlation scales are indeed signatures of criticality, whether this state is robust to fluctuations and initial conditions (and hence criticality is self-organized [4]), and what model parameters define the transition into the power-law regime from the previously well studied regime of SGT with lognormal statistics [2]. We also measure exponents of the power-law tails and study their dependence on the model parameters. References: [1] P. A. Robinson, Solar Phys. **168**, 357 (1996). [2] P. A. Robinson, Phys. Plasmas **2**, 1466 (1995). [3] Yu. Tyshetskiy et al., "Spatiotemporal correlation functions in beam-driven plasmas with fluctuations", submitted to Phys. Plasmas. [4] P. Bak, C. Tang, and K. Wiesenfeld, Phys. Rev. Lett. **59**, 381 (1987).

[1]This work is supported by the Australian Research Council.

UP8.00005 Hamiltonian theory of the nonlinear collisionless tearing mode[1] , F.L. WAELBROECK, P.J. MORRISON, Institute for Fusion Studies, U. Texas, E. TASSI, D. GRASSO, Dipartimento di Energetica, Politenico di Torino — The Hamiltonian formalism constitutes an effective framework for investigating the dynamics of fluid models. A particularly appealing feature of the Hamiltonian formalism is that it readily provides first integrals of the equations governing the configuration and propagation of nonlinear structures such as magnetic islands and solitary waves [1]. Here a newly developed noncanonical Hamiltonian formulation for a two-fluid model describing collisionless reconnection is used to investigate the effects of electron inertia on the nonlinear growth of the collisionless tearing mode. A variational principle is used to obtain a pair of equilibrium equations that take the form of coupled nonlinear elliptic equations for the magnetic flux and the ion stream-function. These equations generalize the Grad- Shafranov equation of MHD. The equilibrium solutions and conservation laws are used to calculate the saturation amplitude of the collisionless tearing mode and the result is compared with numerical simulations.
[1] F. L. Waelbroeck, P. J. Morrison and W. Horton, Plasma Phys. Control. Fusion **46**, 1331 (2004).

[1]Supported by U.S. DOE Contract No. DE-FG03-96ER-54346.

UP8.00006 Toroidal effects on gyrokinetic and fluid models[1] , LINDA SUGIYAMA, M.I.T. — Fluid and gyrokinetic models of high temperature, magnetically confined plasmas both rely on expansion in a gyroradius parameter small compared to a reference size ($\rho_i/L < 1$), but emphasize different aspects of physics. Fluid models retain the effects of toroidal geometry at lowest order but relegate important kinetic effects to ever higher velocity moments, by implicitly taking the gyroradius smaller than a fluid element. Gyro-orbit expansions drop inverse aspect ratio terms in zeroth order (drift kinetic equation), but retain kinetic effects, assuming that the gyro-radius is the most important small parameter. Both kinds of physics are needed to describe high temperature toroidal plasmas. Coupling through the fluid moments requires first or second order. Gyrokinetic models are rigorously derived to all orders for 2D straight field line systems. 3D configurations and toroidal effects greatly complicate the equations, particularly at higher order. Existing models are not completely consistent and these effects are discussed for toroidal plasmas.

[1]Work supported by the U.S. Department of Energy.

UP8.00007 Ballooning Modes for Hall-MHD Plasmas with Shear Flow , ELIEZER HAMEIRI, New York University — Our past work on ballooning modes in MHD plasmas with shear flow[1] has shown that such modes do exist but, rather than being stationary, they drift along the magnetic field line at a poloidal angular velocity equal to the ratio of the toroidal shear flow to the magnetic shear. In the present work we show that the ballooning modes also exist in a Hall-MHD plasma with shear flow, a fact which was in doubt up to now. The mode also drifts along a field line, as in MHD. But it should be noted that in order to go to the ballooning limit ($n \to \infty$), one must also scale the Hall term parameter (the ion skin depth) to be comparable to the width of the mode, with both shrinking to zero. In order to investigate further the properties of the ballooning mode, the equations of which are rather complicated, we use a simplified configuration where the drift of the mode can be removed by transforming to a coordinate system moving along a field line, in a way that leaves a time-independent equation being analyzable by eigenvalues instead of Floquet behavior. So far we have worked out the MHD limit as a basis for comparison, since this case allows for very precise results. The Hall-MHD case is being pursued. [1]E. Hameiri and S.T. Chun, *Phys. Rev. A* **41**, 1186 (1990).

UP8.00008 Preconditioning and Scalability of Implicit Extended MHD Plasma Simulation by FETI-DP Domain Substructuring[1] , ALAN H. GLASSER, Los Alamos National Laboratory — The large range of multiple length and time scales in extended MHD plasma simulation makes it imperative to achieve efficient computation of implicit time steps on petascale parallel computers. The limiting factor is the rate of convergence of Krylov iterative solution of large, sparse matrices, which in turn depends on the condition number of the matrix, the ratio of the largest to smallest eigenvalues. As the size of the problem and the number of processors increase, it is essential that the condition number approximately approach a limit, not rise indefinitely, the property called scalability. Recent analytical work has proven this property for the application of the FETI-DP method of domain substructuring to a limited class of elliptic PDEs [1]. This method provides a coarse solution which assures scalability, and also an effective local method of preconditioning. We explore the extension of these results to more general systems, using computational rather than analytical methods to demonstrate scalability [2].
[1] Axel Klawonn and Olof B. Widlund, Dual-Primal FETI Methods for Linear Elasticity, Comm. Pure Appl. Math. 59, 1523-1572 (2006).
[2] A. H. Glasser and X. Z. Tang, The SEL macroscopic modeling code, Comp. Phys. Comm. 164, 1-3, 237-243 (2004).

[1]This work was supported by DOE Contract No. DE-AC52-06NA25396.

UP8.00009 Ten-Moment Equations For Fluid Modelling of Plasmas , AMMAR HAKIM, Tech-X Corporation — High-order moment fluid equations for simulation of plasmas are presented. The ten–moment equations are a two–fluid model in which time dependent equations are used to advance the pressure tensor. With the inclusion of the full pressure tensor Finite Larmor Radius (FLR) effects are captured. In the absence of collisions, the solution the ten–moment equations can be considered as exact solutions to the Vlasov equation with special initial conditions on the particle distribution function. Collisional effects are included using two different methods. In the first method, the BGK form of the collisional operator is used and in the second, a linearized form of the Coulomb collision operator is used. The dispersion relation of the equation system, both with and without collisions, is presented. In the collisionless case it is shown that, in addition to the usual two–fluid waves, electron Bernstein waves are captured correctly. In the case in which collisions are included, collisional damping rates for the pressure tensor to isotropy are computed. Numerical solution to a few illustrative problems are presented. In the first, solutions to Riemann problems for the ten–moment equations is presented. These differ significantly from the two–fluid and ideal MHD Reimann solutions. Reconnection rate for a fast magentic reconnection problem is computed and compared to kinetic and other fluid models. The stability of a g-mode in a slab plasma is presented.

UP8.00010 Nonstationary Nonlocal Transport Theory of Fully Ionized Two Component Plasma , ZHEN ZHENG, W. ROZMUS, University of Alberta, Edmonton, Alberta, Canada, A. BRANTOV, V. YU. BYCHENKOV, P.N. Lebedev Physics Institute, RAS, Moscow, Russia — Linearized electron transport theory that is fully equivalent to the solution of a Fokker-Planck equation (Bychenkov *et.al.* Phys. Rev. Lett, 75, 4405 (1995)) has been generalized to include ion transport. Starting from the complete Lanadu collision operators expressed in terms of Rosenbluth potentials, electron and ion velocity distribution functions are expressed in terms of infinite series of angular harmonics. Hydrodynamical equations and transport closure relations are derived in response to initial perturbations. The complete set of frequency and k-number dependent transport coefficients has been discussed. Our results show reduction in ion thermal conductivity and ion viscosity for kλ_{ii} >10^{-2} (λ_{ii} - ion-ion collision mean free path, k – wave number related to the inhomogeneity scale length) as compared to standard Chapman-Enskog theory results. Applications of this theory to the calculations of the dynamical form factor, ion-acoustic and entropy modes dispersion relations have been presented. Our results provide an exact limit for the nonlinear transport calculations.

UP8.00011 Electrostatic gyrokinetics in an axisymmetric torus[1] , GRIGORY KAGAN, PETER J. CATTO, MIT — A gyrokinetic change of variables useful for describing electrostatic phenomena in axisymmetric tokamak magnetic field is introduced. In contrast to typical gyrokinetic treatments, canonical angular momentum is taken as the gyrokinetic radial variable rather than the radial guiding center location. Such an approach allows strong radial density gradients, while allowing zonal flow behavior in the presence of strong toroidal rotation. Moreover, neoclassical collision effects naturally enter when the gyrokinetic change of variables is applied to the collision operator. The new, nonlinear gyrokinetic variables are constructed to higher order than is typically the case by generalizing the linear procedure of Lee, Myra and Catto [2]. The nonlinear gyrokinetic equation obtained is expected be useful in analyzing electrostatic behavior in the tokamak pedestal and scrape-off layer. This choice of gyrokinetic variables allows the toroidally rotating Maxwellian solution of the isothermal tokamak limit to be recovered [1]. Moreover, the quasineutrality equation in the long wavelength limit is derived. To verify its consistency, the electrostatic potential obtained from it is compared to the expression found for an isothermal tokamak [1]. References: [1] P. J. Catto and R. D. Hazeltine, Phys. Plasmas **13**, 122508 (2006). [2] X. S. Lee, J. R. Myra and P. J. Catto, Phys. Fluids 26, 223 (1983).

[1]Work supported by U.S. DoE

UP8.00012 Nonlinear global gyrokinetic PIC simulations of collisionless TEM turbulence , S. JOLLIET, B.F. MCMILLAN, T.M. TRAN, X. LAPILLONNE, L. VILLARD, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas, Association Euratom- Suisse, CH-1015 Lausanne, Switzerland, A. BOTTINO, Max Planck Institut fur Plasmaphysik, IPP-EURATOM Association, Garching, Germany, P. ANGELINO, DRFC Association EURATOM-CEA, CEA Cadarache, 19108 St Paul-lez-Durance, France, Y. IDOMURA, Japan Atomic Energy Agency, Higashi-Ueno 6-9-3, Taitou, Tokyo 110-0015, Japan — Micro-instabilities, such as Ion Temperature Gradient modes (ITG) and Collisionless Trapped Electrons Modes (CTEM), are commonly held responsible for anomalous transport observed in tokamaks. While there have been a wide range of nonlinear studies on ITG turbulence, very little is known about the nonlinear physics of CTEM. This work presents the first linear and nonlinear simulations of ITG-CTEM turbulence performed with the global PIC code ORB5 [1]. A linear benchmark of ORB5 against other gyrokinetic codes will be shown. Numerical aspects such as numerical noise will be discussed. The simulations will focus on nonlinear phenomena including detrapping, toroidal coupling, zonal flows, profiles evolution and heat transport.
[1] S. Jolliet *et al.*, to appear in Comput. Phys. Commun.

UP8.00013 Status of edge gyrokinetic turbulence simulation in XGC1[1] , SEUNG-HOE KU, C.S. CHANG, D. ZORIN, L. GREENGARD, New York University, M. ADAMS, Columbia University, J. CUMMINGS, Caltech, P. WORLEY, E. D'AZEVEDO, ORNL, W. LEE, PPPL, S. PARKER, Y. CHEN, University of Colorado at Boulder, Z. LIN, UC Irvine, THE SCIDAC CPES TEAM — Gyrokinetic simulation of a tokamak edge plasma is one of the highest priority research items for ITER and the magnetic fusion program. Due to the complex physical modeling required in the edge plasma (closed and open magnetic field lines with the magnetic separatrix in between, the importance of neoclassical physics, the material wall boundary, steep pressure gradients, a non-Maxwellian distribution function, and the neutral particle physics), most of the gyrokinetic simulation activities have so far been focused on the core plasmas. The status of the gyrokinetic edge turbulence simulation in the XGC1 particle code in the SciDAC Prototype FSP Center for Plasma Edge Simulation (CPES) will be reported. XGC1 includes the above mentioned edge complexities with full- f/delta-f particle technology on an unstructured mesh. Special physics/math/CS features will be discussed. Our current electrostatic turbulence/neoclassical capabilities will be presented and verified. Plans for incorporating full electromagnetic turbulence will also be discussed.

[1]Work supported by US DOE

UP8.00014 Moment approach to the derivation of diffusive and general parallel closures[1] , JEONG-YOUNG JI, ERIC D. HELD, Utah State University — In the moment expansion with the random velocity polynomials instead of the total velocity, the Coulomb collision operators are analytically calculated for any arbitrary order moment. For the electron-ion interaction, the leading terms in the small-mass ratio approximation are derived so that the momentum and energy are conserved. The general moment equations are also explicitly presented. For high collisionality, diffusive closures are derived with all nonlinear terms kept, and as a result, comparable terms to the Braginskii equations are additionally found. For arbitrary collisionality, parallel heat flux and viscous stress are also derived from the general parallel moment equations. The parallel closures can be computed by integrating the gradients of temperature and fluid velocity through kernel functions along a magnetic field line. The kernel functions are simple linear combinations of exponential functions. It is verified that the closure calculation converges with increasing number of moments and that lower collisionality requires more moments. As a practical example, the parallel heat flux is applied to simulate the temperature in SSPX. Finally, a numerical implementation that speeds up the closure calculation is also discussed.

[1]Research supported by the U.S. DOE under grant Nos. DE-FG02-04ER54746, DE-FC02-04ER54798 and DE-FC02-05ER54812.

UP8.00015 A drift ordered short mean-free path description for partially ionized magnetized plasma[1] , ANDREI SIMAKOV, Los Alamos National Laboratory — Effects of neutral particles are very important at the edge of a tokamak and so must be self-consistently accounted for. This has only been done so far for short mean-free path plasma under the high-flow Braginskii ordering [1]. Since plasma flow in modern tokamaks is often comparable with the diamagnetic heat flow divided by pressure it is appropriate to use drift ordering instead. Here we consider short mean-free path plasma consisting of electrons, singly-charged ions, and neutrals. We neglect neutral-neutral and elastic electron-neutral collisions and approximate the neutral-ion charge-exchange cross-section with a constant. We employ drift ordering to evaluate ion, neutral, and electron heat fluxes, viscosity tensors, and momentum and energy exchange terms and formulate a self- consistent system of electron, ion, and neutral fluid equations, thereby generalizing the drift-ordered treatment [2] of fully ionized plasma.
[1] P. Helander, S. I. Krasheninnikov, and P. J. Catto, *Phys. Plasmas* **1**, 3174 (1994) and references therein.
[2] P. J. Catto and A. N. Simakov, *Phys. Plasmas* **11**, 90 (2004).

[1]Work supported by U.S. D.o.E.

UP8.00016 Atomic Models for High Charge State Uranium Plasmas[1] , DAVID FILLMORE, PETER MESSMER, Tech-X Corporation — We present a set of atomic process models for inclusion in electron-Uranium ion plasma simulations. These include an adaptation of the binary encounter dipole model of Kim and Rudd (1994) for electron impact ionization, the Burgess general formula for dielectronic recombination rates, and the semiclassical impact parameter approximation for ion-atom charge exchange. The orbital binding energies and oscillator strengths are estimated with a multi-configuration Dirac Fock Model. Comparisons are made to existing experimental measurements of electron impact ionization for neutral Uranium (Halle et al., 1981) and for U(10+), U(13+) and U(16+) (Gregory et al., 1990). These models have been developed for use in simulations of U(28+) through U(35+) production at the the Versatile Electron-Cyclotron-Resonance Ion Source for Nuclear Science (VENUS) at Lawrence Berkeley Laboratory.

[1]Work supported by the U.S. DOE Office of Science, Office of Nuclear Physics, under grant DE-FG02-05ER84173.

UP8.00017 Experiments for measuring EIR and MAR in detaching plasmas in the PISCES-A divertor simulator , LAIZHONG CAI, GEORGE TYNAN, ERIC HOLLMANN, DAISUKE NISHIJIMA, University of California, San Diego — Traditionally, Electron-Ion Recombination (EIR) is considered the dominant volume recombination process in detaching divertors. However, Molecular-Activated Recombination (MAR) was found both in PISCES-A and NAGDIS-II, which could be an important path to make a detaching plasma. The EIR sink rate is obtained in a pure magnetized He plasma column by absolutely calibrated high n (principle quantum number) He-I line emission associated with EIR. A small amount of H_2 gas is then injected into this plasma, resulting in the collapse of EIR emission with sufficient H_2 gas density. Since MAR produces H neutrals in a low excited or ground states in contrast to EIR associated with highly excited states, it will not bother the measurements of EIR. Using an integral form of the particle conservation equation, the MAR sink rate is derived with the measured parallel flux, ionization source, EIR sink and anomalous radial flux to the wall. Finally, the EIR and MAR are demonstrated quantitatively. The role of MAR is shown against the percentage of H_2 gas.

UP8.00018 Molecular Ion Effects in IEC Modeling[1] , GILBERT EMMERT, JOHN SANTARIUS, Fusion Technology Institute, University of Wisconsin — A 1-D model for the effect of various molecular and atomic processes (charge exchange, ion impact ionization, and dissociative processes) between deuterium ions (D^+, D_2^+, and D_3^+) and the background gas on the performance of spherical, gridded IEC devices has been developed. Ions pass through the anode grid primarily as an arbitrary mixture of D^+, D_2^+, and D_3^+ ions and, while being accelerated by the electrostatic potential, interact with the background gas to produce a source of cold ions (D^+ and D_2^+) through interactions with the background D_2 gas. These cold ions are accelerated by the potential and produce additional cold ions through interactions with the background gas. A formalism has been developed which includes the bouncing motion of ions in the potential well and sums over all generations of cold ions. This leads to a set of coupled Volterra integral equations. The integral equations are solved numerically to yield the energy spectrum of the ion and fast neutral flux; the resulting neutron production rate is calculated. Parametric surveys of the effect of the ion mixture in the source region and comparison with experimental data for the Wisconsin IEC devices will be presented.

[1]Research supported by the US Dept. of Energy under grant DE-FG02-04ER54745.

UP8.00019 Deuterium cluster model for low energy nuclear reactions (LENR) , GEORGE MILEY, Dept. NPRE, Univ of Illinois, Urbana-Champaign, HEINRICH HORA, Dept. Theoret. Phys.. Univ. New South Wales, Sydney, Australia — For studying the possible reactions of high density deuterons on the background of a degenerate electron gas, a summary of experimental observations resulted in the possibility of reactions in pm distance and more than ksec duration similar to the K-shell electron capture [1]. The essential reason was the screening of the deuterons by a factor of 14 based on the observations. Using the bosonic properties for a cluster formation of the deuterons and a model of compound nuclear reactions [2], the measured distribution of the resulting nuclei may be explained as known from the Maruhn-Greiner theory for fission. The local maximum of the distribution at the main minimum indicates the excited states of the compound nuclei during their intermediary state. This measured local maximum may be an independent proof for the deuteron clusters at LENR.

[1] H. Hora, G.H. Miley et al. Physics Letters A175, 138 (1993)
[2] H. Hora and G.H. Miley, APS March Meeting 2007, Program p. 116

UP8.00020 New formula of Debye length in solid metallic hydrogen , KAZUNORI SHIBATA, RYOSUKE KODAMA, Graduate School of Engineering, Osaka University — In arbitrary quasineutral states, ionic potential is somewhat screened by electrons. The degree of the screening is represented by Debye screening length. The Debye length varies proportional to square root of the temperature in plasma state. When the temperature drops to the Fermi temperature, electrons undergo Fermi degenerate and the Debye length becomes independent of the temperature. Such situation also appears in solid states. We have researched in solid metallic hydrogen because it is said to be a high temperature superconductor and is an ideal matter to treat the Debye screening by the lack of orbital electrons. By taking into account the changes in electronic quantum statistical state, the formula of the Debye length in the superconductive state was derived. The Debye length in the superconductive state again depends on the temperature by bosonization of the electrons. As a one application, we also have calculated the penetration probability by using the WKB approximation. The probability at $n = 10^{31}\mathrm{m}^{-3}$ and T=10K is comparative that of a particle of about 7.5 eV penetrates bare Coulomb potential.

UP8.00021 The Explanation of Quantum Teleportation and Entanglement Swapping , RUSSELL MOON, Dr., VICTOR VASILIEV, Pr. — According to the Vortex Theory, the rotation of a particle causes the surrounding three-dimensional space to rotate creating the particle's electromagnetic characteristic. Because three-dimensional space is the surface of fourth-dimensional space, this rotation extends slightly downward into the fourth-dimensional volume beneath. If two photons possessing complementary polarizations are "entangled", this extreme closeness forces their rotations extending into fourth-dimensional space to join together forming a vortex. When the particles are separated, the vortex between them remains. A change in the orientation of a photon at one end of the vortex travels in a wave down the length of the vortex creating a change in the orientation of the photon at the other end. Entangled separated particles of matter such as electrons are similarly connected and effected by each other. The breaking and reconnecting of these vortices also explains the phenomenon of entanglement swapping. 1 R.G. Moon, *The Possible Existence of a New Particle: the Neutral Pentaquark*? Book of materials, The Scientific Seminar Ecology and Space 1, February 22, 2005, Saint-Petersburg, Russia, 2005.

UP8.00022 DIII-D II —

UP8.00023 Overview of DIII-D Experimental Results and Program Plans[1] , T.S. TAYLOR, General Atomics, DIII-D TEAM — The DIII-D research program is addressing urgent ITER R&D issues, improving Advanced Tokamak operation, and using an expanding set of control tools and diagnostics to better understand the physics of high performance tokamaks. Resistive wall mode experiments with counter beam injection addressed stability and feedback control in slowly rotating ITER-relevant plasmas, providing new data to compare with code predictions. ELM-control experiments using internal and external coils point to a physics basis for design of similar coils for ITER, and new disruption mitigation results show promise for suppression of runaway electrons. Steadily increasing ECH and fast wave power (2.4 MW ECH and 3.1 MW FW) provides the means to heat electrons to vary collisionality and T_e/T_i to study turbulent transport with improved diagnostics to measure a broad spectrum of density and temperature fluctuations, and will improve current profile control in AT plasmas. In the near future, we anticipate increased long-pulse ECH power to extend noninductive high bootstrap fraction AT performance; longer-term plans include 10 s operation at full field.

[1]Supported by the US DOE under DE-FC02-04ER54698.

UP8.00024 3D Structure and Dynamics of ELMs[1] , T.E. EVANS, GA, J.G. WATKINS, SNL, I. JOSEPH, J.H. YU, UCSD, M. JAKUBOWSKI, MPI, O. SCHMITZ, FZ-Juelich — Understanding the global topology and dynamics of edge localized modes (ELMs) is essential for predicting transient loading on plasma facing surfaces. Fast visible line emission images taken during ELMs consistently show filament-like helical structures that expand radially outward from the pedestal while rotating toroidally. Fast infrared camera images show a rapidly evolving splitting and broadening of the divertor heat flux footprints that appear to be correlated with non-axisymmetric divertor currents. In single-null poloidally diverted configurations, these experimental signatures appear to be topologically consistent with a splitting of the separatrix into a set of invariant manifolds resulting in an object known as a homoclinic tangle in dynamical systems theory. Here, we describe a model in which helical currents flowing along this tangle amplify its size and toroidal phase. We compare predictions from this model to experimental measurements of the properties of filament-like structures measured with various DIII-D fast diagnostic systems.

[1]Supported by the US DOE under DE-FC02-04ER54698, DE-AC04-94AL85000, and DE-FG02-04ER54758.

UP8.00025 Modeling of the Plasma Response to Resonant Magnetic Perturbations with the NIMROD Code , S.E. KRUGER, Tech-X Corporation, I. JOSEPH, Univ. of California-San Diego, E.D. HELD, Utah State University, D.D. SCHNACK, Univ. of Wisconsin-Madison, T.E. EVANS, General Atomics, R.A. MOYER, Univ. of California-San Diego — Resonant magnetic perturbations (RMPs) have successfully been used to control ELMs in the DIII-D tokamak[1] In these experiments, internal coils are used to tailor the mode amplitude spectrum at the separatrix with the goal of affecting transport at the edge. Intuitively, inducing islands at the separatrix would cause a stochastic edge and enhanced electron temperature transport; however, experimental evidence shows that both the ion and electron temperature gradients are relatively unchanged, while the density gradient is substantially reduced. Modeling of these experiments by initial-value extended magnetohydrodynamics codes is attractive because the essential features, magnetic reconnection, parallel and perpendicular transport, and ELM stability have all been independently studied. The challenge of modeling the experimental device lies in the extreme range of time scales with the ramp rate of I-coil currents being on the order of milliseconds and the Alfven time being sub-microseconds. Here we show results of modeling just the the field error penetration problem. We extend the numerical simulations of Fitzpatrick[2] to three-dimensional geometry, two-fluid physics, and anisotropic viscosity.

[1]R. A. Moyer, T. E. Evans, T. H. Osborne, et al., Phys. Plasmas **12** (2005) 056119
[2]Fitzpatrick, Physics of Plasmas, **10** (2003) 1782

UP8.00026 Effect of RMP on Edge Density Profiles and Fluctuations in DIII-D[1] , L. ZENG, T.L. RHODES, E.J. DOYLE, G. WANG, W.A. PEEBLES, A.E. WHITE, UCLA, T.E. EVANS, General Atomics, R.A. MOYER, UCSD, M.E. FENSTERMACHER, LLNL — Resonant magnetic perturbation (RMP) has been used successfully to suppress Type-I edge localized modes (ELM) in DIII-D. In these ELM-suppressed operations, the detailed edge density profile and evolution of the fluctuations have been investigated in order to study the effect of RMP on edge transport. Utilizing a high-resolution profile reflectometer (Δt=25 μs, Δr $\geq$ 2 mm), it is observed that with even parity n=3 RMP, pellet injection results in a larger increase in the scrape-off layer density and a smaller increase in the pedestal density gradient, as compared with no RMP. This result is consistent with the decay time of pellet-induced core density perturbation with RMP being shorter than without RMP, indicating an enhanced particle transport during the ELM-suppressed phase. The detailed density profile and fluctuation evolution will be presented for various RMP configurations, e.g. n=1, n=3, in both low and high collisionalities.

[1]Supported by the US DOE under DE-FG03-01ER54615, DE-FC02-04ER54698, DE-FG02-04ER54758, and W-7405-ENG-48.

UP8.00027 Particle Transport in RMP ELM Suppressed H-modes[1] , R.A. MOYER, J.A. BOEDO, V.A. IZZO, I. JOSEPH, S. MORDIJCK, D.L. RUDAKOV, J.H. YU, UCSD, T.E. EVANS, N.H. BROOKS, T.H. OSBORNE, P. GOHIL, J.S. DEGRASSIE, A.W. LEONARD, GA, M.E. FENSTERMACHER, C.J. LASNIER, LLNL, J.G. WATKINS, SNL, T.C. JERNIGAN, ORNL, M. JAKUBOWSKI, MPI-Griefswald, O. SCHMITZ, FZJ, G. WANG, A.E. WHITE, L. ZENG, UCLA, G.R. MCKEE, U. Wisc.-Madison, C. ROST, J.R. DORRIS, MIT — Suppression of Type I ELMS with n=3 edge resonant magnetic perturbations (RMP) depends on reducing the pedestal pressure gradient below the peeling-ballooning mode stability limit. This pressure gradient reduction results from a reduction in pedestal particle density and effective particle confinement time τ_p*. Recent experimental results suggest that this τ_p* reduction arises from at least two mechanisms: increased ion-scale turbulence in the region 1>r/a>0.75, and improved coupling of the plasma to the pump due to strike point splitting. These mechanisms are observed to increase the density at the pump entrance, leading to improved pumping efficiency and lower τ_p*.

[1]Work supported by US DOE under DE-FG02-04ER54758, DE-FC02-04ER54698, W-7405-ENG-48, DE-AC04-94AL85000, DE-AC05-00OR22725, DE-FG03-01ER54615, DE-FG02-89ER53296, and DE-FG02-04ER54235.

UP8.00028 Modeling of Global Particle Balance in ELMing and RMP ELM-Suppressed DIII-D Discharges With SOLPS5-EIRENE[1] , S. MORDIJCK, I. JOSEPH, R.A. MOYER, G.R. TYNAN, UCSD, L.W. OWEN, ORNL, T.E. EVANS, T.H. OSBORNE, GA, X. BONNIN, LIMHP-CNRS, D. COSTER, MPI-G, D. REITER, FZ Juelich — The global particle balance in single-null DIII-D H-mode plasmas, with density control using the lower cyropump, is studied with a 2D fluid code coupled to a Monte-Carlo neutral code, SOLPS5-EIRENE. We compare DIII-D discharges with type-I ELMs to ELM-suppressed discharges using n=3 I-coil resonant magnetic perturbations (RMPs). We observe that RMP leads to a strong reduction in the density. This may result from an increase in stochastic particle advection, increased fluctuation driven transport or improved coupling of the plasma to the pump due to changes in the magnetic footprints. To identify the importance of each effect, we construct a grid and derive transport parameters to fit the radial profiles between ELMs in an ELMing discharge. We investigate the relative impact of changes in the pumping efficiency by comparing the numerical profiles to the experimental RMP profiles.

[1]Supported by the US DOE under DE-FG02-04ER54758, DE-AC05-00OR22725, and DE-FC02-04ER54698.

UP8.00029 Strike Point Splitting in RMP-ELM-free H-mode[1] , I. JOSEPH, R.A. MOYER, UCSD, T.E. EVANS, M.J. SCHAFFER, W.P. WEST, GA, M. JAKUBOWSKI, A.M. RUNOV, R. SCHNEIDER, MPI, S.V. KASILOV, Kharkov-IPT, O. SCHMITZ, FZ-Juelich, M.E. FENSTERMACHER, M. GROTH, C.J. LASNIER, LLNL, J.G. WATKINS, SNL — The E3D two-fluid code is used to model the effect of resonant magnetic perturbations on DIII-D thermal transport. The strike points are predicted to develop multiple striations determined by the invariant manifolds of the perturbed field, and the heat flux distribution is predicted to be well-correlated with the local connection length. Although filtered optical cameras observe striations in particle flux, the energy fluxes measured by infrared cameras and Langmuir probes do not appear to display significant splitting. This indicates that the perturbed field lines do not penetrate far inside the unperturbed separatrix. This is consistent with the fact that the predicted thermal transport is too large to match measured pedestal profiles. Both results may indicate that the rotational plasma response limits the stochastic field to a thin layer near the separatrix.

[1]Work supported by US DOE under DE-FG02-05ER54809, DE-FG02-04ER54758, DE-FC02-04ER54698, W-7405-ENG-48, and DE-AC04-94AL85000.

UP8.00030 Fast Imaging of ELM Structure and Dynamics in DIII-D[1] , J.H. YU, J.A. BOEDO, E.M. HOLLMANN, R.A. MOYER, D.L. RUDAKOV, UCSD, P.B. SNYDER, GA — Fast-framing images of CIII and D_α emission in the low-field-side (LFS) plasma boundary of DIII-D show that ELMs are helical filamentary structures that rotate toroidally. The filaments propagate radially outward at $v_r \sim$500 m/s during the nonlinear phase, and result in plasma-wall interactions that are poloidally localized within 15 cm of the midplane. The measured mean poloidal width of the filament is 3 cm, and the ELM toroidal mode number n ranges from 10 to 35. ELM structure and dynamics vary with plasma density, possibly because ELMs are driven by a peeling type of mode in low density plasmas and are driven by a coupled peeling-ballooning mode in high density. At high collisionality (ν_{ped}*=0.50), ELMs begin with an unstable filament or group of filaments at the LFS midplane region. Onset of the ELM-induced radiation in the divertor is delayed by as much as 0.8 ms compared to the midplane signals. In low collisionality (ν_{ped}*=0.25) discharges, the midplane and divertor ELM signals appear simultaneously, possibly suggesting a more poloidally symmetric mode structure.

[1]Work supported by US DOE under DE-FG02-04ER54758 and DE-FC02-04ER54698.

UP8.00031 ELM Triggering From Deuterium Pellets Injected into DIII-D[1] , L.R. BAYLOR, T.C. JERNIGAN, Oak Ridge National Laboratory, T.E. EVANS, P.B. PARKS, General Atomics, M.E. FENSTERMACHER, Lawrence Livermore National Laboratory, R.A. MOYER, University of California-San Diego — Deuterium fueling pellets have been injected into DIII-D plasmas from five different locations and under different plasma H-mode conditions. Edge localized modes (ELMs) have been triggered from pellets injected from all locations and under all the H-mode scenarios thus far explored. Pellets injected into plasmas with ELMs suppressed by a resonant magnetic perturbation are also observed to trigger one or more ELM like events. Experimental details of the pellet triggering of ELMs on DIII-D will be reviewed. In addition a pellet dropper has been installed on DIII-D for ELM pacing studies. Initial results from the slow 1mm pellets dropped into the edge plasma will be presented.

[1]Supported by US DOE under DE-AC05-00OR22725, DE-FG03-95ER54309, DE-FC02-04ER54698, W-7405-ENG-48, and DE-FG02-04ER54758.

UP8.00032 Modeling of Perturbation Magnetic Field Based on Scrape-Off Layer Currents (SOLCs) During ELMs in DIII-D[1] , H. TAKAHASHI, E.D. FREDRICKSON, Princeton Plasma Physics Laboratory, M.J. SCHAFFER, General Atomics — The poloidal perturbation magnetic field ($B_{\delta B}$) measured by the Mirnov diagnostic at the peak of ELMs in H-mode discharges on the DIII-D tokamak exhibits idiosyncratic features in its poloidal variation: the field peaks in the divertor, and is larger ("anti-ballooning") and opposite in sign on the inboard side in comparison with the outboard side. A model, developed for calculating $B_{\delta B}$ consistent with measured scrape-off layer current (SOLC), reproduces these idiosyncratic features. A narrow magnetic structure was also observed by the Mirnov diagnostic at the outboard mid-plane in some ELMs, which appeared to be qualitatively similar to filaments reported earlier in DIII-D [1] and NSTX [2]. The SOLC-based model also reproduces such a filament structure. [1] E.J. Strait, et al., Phys. Plasmas **4**, 1783 (1997). [2] R. Maingi, et al., Phys. Plasmas **13**, 092510 (2006).

[1]Supported by the US DOE under DE-AC02-76CH03073 and DE-FC02-04ER54758.

UP8.00033 Target Plate Profiles During ELM Suppression Experiments on DIII-D[1] , J.G. WATKINS, SNL, T.E. EVANS, C.J. MURPHY, GA, M.J. MARTIN, Cornell U., A. NELSON, U. of St Thomas, M. JAKUBOWSKI, KFZ-Juelich, I. JOSEPH, R.A. MOYER, UCSD, C.J. LASNIER, M.E. FENSTERMACHER, LLNL — Radial profiles of target plate plasma conditions during ELM suppressed conditions have been measured with the new DIII-D lower divertor Langmuir probe array. ELM suppression was accomplished using n=3 resonant magnetic perturbations [1]. Evidence of the n=3 mode structure of the perturbation can be seen most clearly in the V_f profile on the target plate. The spacing of the multiple peaks in the V_f profile is similar to predictions of the TRIP3D field line integration code. T_e values >100 eV and V_f values down to –150 V were measured. We observe resonant behavior of the target plate parameters near the q_{95} value for maximum magnetic perturbation. Heat flux from the Langmuir probe measurements will be compared with infrared cameras and thermocouples. The resulting sheath power transmission factor profile will be shown. [1] T.E. Evans, *et al.,* Phys. Rev. Lett. **92**, 235003 (2004).

[1]Supported by US DOE under DE-AC04-94AL85000, National Undergraduate Fusion Fellowship, DE-FC02-04ER54698, DE-FG02-04ER54758, and W-7405-ENG-48.

UP8.00034 Divertor Heat and Particle Fluxes During ELM Control Experiments[1] , O. SCHMITZ, FZJ, M.W. JAKUBOWSKI, MPI, T.E. EVANS, M.J. SCHAFFER, W.P. WEST, GA, M.E. FENSTERMACHER, M. GROTH, C.J. LASNIER, LLNL, I. JOSEPH, R.A. MOYER, UCSD, B. UNTERBERG, H. FRERICHS, FZJ — In experiments exploring ELM suppression by resonant magnetic perturbation (RMP) as a technique for ITER, the manipulation of divertor heat and particle fluxes is of vital interest. To investigate these effects, a fast IR camera and CCD cameras equipped with D_α, CII or CIII interference filters were used during RMP ELM control experiments at DIII-D. In general, a splitting of the inner and outer divertor strike lines was observed. This is caused by splitting of the invariant separatrix manifolds that form magnetic footprints on the wall elements. Parallel particle and heat fluxes are transported along these field lines forming a characteristic pattern on the divertor target. The measured patterns are compared to magnetic footprints modeled with the TRIP3D code to identify the topology of the heat and particle flux channels. Based on that, the occurrence of complete ELM suppression is correlated to the measured and modeled target patterns.

[1]Supported by US DOE under DE-FC02-04ER54698, DE-FG02-04ER54758, and W-7405-ENG-48.

UP8.00035 Radiating Divertor Behavior in Single- and Double-Null Plasmas in DIII-D[1] , T.W. PETRIE, N.H. BROOKS, A.W. HYATT, M.J. SCHAFFER, M.R. WADE, W.P. WEST, General Atomics, M.E. FENSTERMACHER, M. GROTH, C.J. LASNIER, LLNL, J.G. WATKINS, SNL — The ability to concentrate impurities in the divertor region to provide effective radiative divertor operation has been found on DIII-D to be sensitive to the divertor magnetic geometry and the grad-B drift direction. Argon impurities were injected into the private flux region of one divertor, while deuterium flow into the divertors was simultaneously enhanced by a combination of midplane gas puffing and divertor cryopumping. For DN plasmas it was difficult to balance the radiated power between divertors during argon injection; significant increases in radiated power and argon concentration were observed mostly in the divertor that was *opposite* the grad-B drift direction. For SN plasmas, there was a higher divertor argon accumulation in the divertor when the grad-B drift direction was away from the dominant X-point, and so this setup may provide the best prospect of successfully coupling a radiating divertor approach to a high performance H-mode plasmas.

[1]Work supported by US DOE under DE-FC02-04ER54698, W-7405-ENG-48, and DE-AC04-94AL85000.

UP8.00036 The Influence of High Field Side Recycling and Impurity Sources on Divertor Detachment in Simulations of Ohmic Discharges of the ASDEX Upgrade and DIII-D Tokamaks[1]

, M. WISCHMEIER, A. KALLENBACH, A.V. CHANKIN, D. COSTER, R. DUX, J. HARHAUSEN, H.W. MUELLER, IPP Garching, M. GROTH, LLNL, X. BONNIN, LIMHP, ASDEX UPGRADE TEAM — In the framework established under the International Tokamak Physics Activity (ITPA) Divertor and SOL working group a series of ohmic discharges with similar plasma parameters have been performed in ASDEX Upgrade and in DIII-D. The SOLPS code is tested against these experimental data at the onset of divertor detachment. The presentation focuses on identifying numerically the impact of divertor geometry, target material composition as well as high field side (HFS) recycling and impurity sources on the onset and degree of detachment along the inner target. Physics processes to explain the observed asymmetry between the inner and outer target ion fluxes with increasing line-averaged density are discussed.

[1]Supported by the US DOE under W-7405-ENNG-48 and the Intra-European Fellowship (EURATOM).

UP8.00037 Measurement and Modeling of Carbon Flows in the Main SOL of the DIII-D Tokamak[1]

, M. GROTH, M.E. FENSTERMACHER, G.D. PORTER, M.E. RENSINK, T.D. ROGNLIEN, LLNL, J.A. BOEDO, D.L. RUDAKOV, J.H. YU, UCSD, N.H. BROOKS, GA, R.C. ISLER, ORNL, J.G. WATKINS, SNL — Carbon ion velocities of $\sim$1/2 of the deuterium ion sound speed in the direction of the inner divertor were measured in the scrape-off layer (SOL) at the top of DIII-D low-density, low-confinement plasmas with the ion $\mathbf{B}\times\nabla B$ drift toward the divertor. The use of upper single-null discharges and injection of methane from the bottom of the DIII-D vessel in toroidally symmetric fashion enabled simultaneous measurements of the flow of deuterium ions with a reciprocating Langmuir probe and of low charge-state carbon ions with a tangential viewing spectrometer and cameras. Modeling of the SOL with the UEDGE code predicts significantly weaker flow of deuterium ions in the SOL compared with the data, leading to an underestimate of the carbon flow in the main SOL. The dependences of the simulated flows on the assumed radial transport model and boundary conditions are investigated and will be presented.

[1]Work supported by the US DOE under W-7405-ENG-48, DE-FG02-04ER54758, DE-FC02-04ER54698, DE-AC05-00OR22725, and DE-AC04-94AL85000.

UP8.00038 Direct Spectroscopic Measurement of Fast Ionic Flow in the Main SOL of Diverted Plasmas on the DIII-D Tokamak[1]

, N.H. BROOKS, W.P. WEST, General Atomics, R.C. ISLER, ORNL, M. GROTH, LLNL, J.A. BOEDO, UCSD — Flow velocities in the SOL at the crown of the main plasma have been determined by direct measurement of Doppler shifts in the spectral line profiles of C II and C III. In single-null discharges with $\mathbf{B}\times\nabla B$ drift into the divertor, flow toward the inner divertor is found, with C II and C III velocities of $\sim 8\times10^5$ and $\sim 1.5\times10^6$ cm/s, respectively. The magnetic field value deduced from Zeeman splitting of these spectral lines is used to spatially localize their emissions to flux surfaces outside the separatrix, with normalized ψ-values of 1.04 and 1.045, respectively. The spectroscopically deduced C III velocity is consistent with reciprocating probe measurements of fuel ion Mach number assuming full entrainment of the doubly ionized carbon ion on the flux surface where its emission is localized. TV images of the breakup fragments from injected methane gas provide additional confirmation of the SOL impurity flow.

[1]Supported by the US DOE under DE-FC02-04ER54698, DE-AC05-00OR22725, W-7405-ENG-48, and DE-FG02-04ER54758.

UP8.00039 Indications of an Inward Pinch in the Inner SOL of DIII-D From ^{13}C Deposition Experiments[1]

, J.D. ELDER, P.C. STANGEBY, A.G. MCLEAN, U. Toronto, S.L. ALLEN, M.E. FENSTERMACHER, M. GROTH, LLNL, J.A. BOEDO, D.L. RUDAKOV, UCSD, B.D. BRAY, N.H. BROOKS, A.W. LEONARD, W.P. WEST, GA, W.R. WAMPLER, J.G. WATKINS, SNL, D.G. WHYTE, MIT — ^{13}C methane puffing experiments were conducted on DIII-D in both L- and edge localized mode H-mode conditions. The puffing was toroidally symmetric into the crown of a series of well-characterized LSN discharges in which the plasma conditions, carbon emissions, core carbon increment and ^{13}C deposition pattern were measured. The hydrocarbon breakup and subsequent carbon transport were modeled using the OEDGE interpretive code. The carbon is followed in OEDGE until it deposits on surfaces. Replicating the experimental deposition requires assuming in the code both fast parallel transport as well as a pinch/drift in the inner scrape-off layer towards the separatrix of 10 to 20 m/s in both L and H mode. Radial variation of the fast parallel flow and re-erosion of carbon are investigated as alternative hypotheses to a pinch.

[1]Supported by the US DOE under W-7405-ENG-48, DE-FG02-04ER54758, DE-FC02-04ER54698, DE-AC04-94AL85000, and DE-FG02-04ER54762.

UP8.00040 Tritium Recovery From Carbon Co-deposits: *ex situ* Studies in Preparation for an *in situ* Thermal Oxidation Experiment in DIII-D[1]

, C. TSUI, J.W. DAVIS, A.A. HAASZ, B.W.N. FITZPATRICK, A.G. MCLEAN, P.C. STANGEBY, Y. MU, U. Toronto, S.L. ALLEN, LLNL, W.P. WEST, P.L. TAYLOR, K.L. HOLTROP, A.W. HYATT, R.L. BOIVIN, GA, K. UMSTADTER, UCSD — Tritium trapping in carbon co-deposits is potentially a major cause of T retention in ITER. A possible solution is "thermo-oxidation," involving sub-atmospheric molecular O_2 at 250^o-350^oC. Ex situ lab tests (at U. Toronto) of graphite tiles removed from DIII-D have demonstrated the method in principle and generated a comprehensive database on removal rates. Ex situ tests were also performed for special components (e.g., diagnostic mirrors) used in DIII-D to assess potential damage. The next step is in situ demonstration in DIII-D to show that the D (as proxy for T) and C removed from the tiles actually leaves the vessel, that vessel components are not damaged, and that plasma operation can be recovered quickly. Lab results and implications for the in situ test are discussed.

[1]Work supported by the Natural Sciences and Engineering Research Council of Canada and by US DOE under W-7405-ENG-48, DE-FC02-04ER54698, and DE-FG02-04ER54578.

UP8.00041 Results From the Upgraded Porous Plug Injection System for Studies of Hydrocarbon Dissociation and Transport in DIII-D[1]

, A.G. MCLEAN, J.W. DAVIS, Y. MU, P.C. STANGEBY, U. Toronto, S.L. ALLEN, R. ELLIS, M.E. FENSTERMACHER, M. GROTH, C.J. LASNIER, LLNL, B.D. BRAY, N.H. BROOKS, T.W. PETRIE, W.P. WEST, C.P.C. WONG, GA, D.G. WHYTE, MIT, J.A. BOEDO, E.M. HOLLMANN, D. NISHIJIMA, D.L. RUDAKOV, UCSD, R.J. COLCHIN, R.C. ISLER, ORNL, J.G. WATKINS, SNL, S. BREZINSEK, M. JAKUBOWSKI, A. KRATER, Juelich — Calibrated spectroscopic measurements of dissociation fragments resulting from hydrocarbon influx in a tokamak divertor have been taken with the use of the Mk II Porous Plug Injector (PPI) in DIII-D. The PPI was upgraded to include a small orifice flow restrictor for more precise gas flow control, achieving flow rates corresponding to sputtering yields of 0.5%-2% in attached and detached divertor plasmas. Results and analysis of digital video, and medium and high resolution spectroscopic data collected are presented and compared with those of the Mk I PPI and similar experiments at JET, TEXTOR, and ASDEX.

[1]Supported by the US DOE under W-7405-ENG-48, DE-FC02-04ER54698, DE-FG02-04ER54762, DE-FG02-04ER54758, DE-AC05-00OR22725, and DE-AC04-94AL85000 and NSERC Canada.

UP8.00042 Dust Particles Observed by Laser Scattering at DIII-D[1] , B.D. BRAY, W.P. WEST, General Atomics, D.L. RUDAKOV, UCSD — Studies of dust particles observed by Rayleigh/Mie scattering of ND:YAG lasers during plasma operations at DIII-D show correlations with plasma configuration. Dust particles are primarily observed outside the last closed flux surface of the plasma. The mean particle density has been observed to be near 400 m^{-3} in both divertor scrape-off layer regions, corresponding to an upper or lower single-null configuration. The inferred particle size ($\sim$100 nm) indicates this represents a small carbon density relative to measured ionized carbon density in the plasma and consequently not believed to be a significant source of impurities. However, understanding the dust dynamics remains important because of its safety implications in future burning plasma reactors. In addition, in DIII-D, the dust density varies with the phase of the plasma discharge and plasma parameters. The dust density is roughly twice as large in ELMing H-mode discharges compared to QH- or L-mode.

[1]Supported by the US DOE under DE-FC02-04ER54698 and DE-FG02-04ER54758.

UP8.00043 Inference of Thermal and Momentum Transport Coefficients in the DIII-D Edge Pedestal[1] , W.M. STACEY, Georgia Tech., R.J. GROEBNER, GA — New methodologies for inferring thermal and momentum transport coefficients from measured temperature, density and velocity profiles in the edge plasmas have been developed. The thermal interference methodology, which takes into account radiation and atomic physics cooling, recycling neutrals and convection, in the determination of conductive heat flux profiles, has been applied to the ELM-free phase of a discharge [1]. Now, time-resolved profile data sets averaged over similar inter-ELM intervals have been developed for two discharges. The methodology has been extended to take into account the measured reheating and density buildup in the pedestal between ELMs, and ion and electron thermal diffusivities have been inferred for the various sub-intervals (e.g. 10%-20%, 80%-90%) in the inter-ELM interval. An analogous methodology has been developed for inferring toroidal angular momentum and poloidal momentum transport rates from measured toroidal and poloidal velocity measurements, respectively, and applied to the same two data sets.
[1] W.M. Stacey and R.J. Groebner, Phys. Plasma **13**, 072510 (2007).

[1]Work supported by US DOE under DE-FC02-04ER54698.

UP8.00044 Dependence of H-mode Power Threshold on Input Torque and Toroidal Plasma Rotation in the DIII-D Tokamak[1] , P. GOHIL, General Atomics, G.R. MCKEE, D.J. SCHLOSSBERG, U. Wisc.-Madison, G. WANG, UCLA — The power required to induce the L-H transition is dependent on the applied beam torque. For upper single-null discharges in which the ion ∇B drift is away from the X-point, the L-H transition power threshold is reduced by up to a factor of 3 by changing from predominantly co (4-6 MW) to predominantly counter-injection (<2 MW). Lowered L-H transition power thresholds are also observed with reduced input torque in discharges with the ion ∇B drift towards the X-point, but to a lesser degree. For the first time, an H-mode transition was induced by slowly reducing the input torque at constant input power by slowly varying the mix of co- and counter-beam injection. The mechanisms for such a torque dependence are being investigated from analyses of the edge plasma rotation, the edge radial electric field and the edge plasma turbulence. Preliminary results indicate large changes in the poloidal velocity shear of the edge turbulent eddies prior to the L-H transition that may be strong enough to induce the transition.

[1]Supported by US DOE under DE-FC02-04ER54698, DE-FG02-89ER53296, and DE-FG03-01ER54615.

UP8.00045 H-Mode Pedestal Toroidal Velocity in DIII-D[1] , J.S. DEGRASSIE, R.J. GROEBNER, K.H. BURRELL, General Atomics, W.M. SOLOMON, PPPL, DIII-D TEAM — Tokamak discharges have nonzero toroidal momentum in the absence of any auxiliary injected torque [1]. It is important to understand this "intrinsic rotation" in order to extrapolate to burning plasmas. The interface between the plasma and the boundary can possibly provide an edge momentum flux, or nonzero velocity boundary condition. In order to see if it is possible to extract any boundary condition we have looked at the DIII-D database of measurements of toroidal and poloidal velocity in the region of the edge density pedestal in H-mode discharges, including Ohmic and ECH H-modes with no auxiliary torque, discharges with rotation driven by uni-directed neutral beam injection (NBI), and discharges with near-balanced NBI, which portend to allow measurements of intrinsic rotation at high auxiliary power levels. The consistency of an NBI momentum flux through the pedestal vs intrinsic rotation will be evaluated. Comparison will be made with applicable neoclassical and turbulence theories of intrinsic rotation. [1] J.S. deGrassie, *et al.,* Phys. Plasma **14**, 056115-1 (2007).

[1]Supported by the US DOE under DE-FC02-04ER54698 and DE-AC02-76CH03073.

UP8.00046 Effects of Toroidal Rotation on Edge Turbulence and the L-H Power Threshold[1] , D.J. SCHLOSSBERG, G.R. MCKEE, M.W. SHAFER, U. Wisc.-Madison, K.H. BURRELL, P. GOHIL, R.J. GROEBNER, T.C. LUCE, GA, G. WANG, UCLA — Edge turbulence dynamics, flows, and flow shear are found to depend strongly on the injected neutral beam torque in DIII-D plasmas. Likewise, the power threshold required to induce a transition from low- to high-confinement mode decreases by a factor of 2-3 as torque is varied from the co to counter current directions. Turbulence characteristics such as the poloidal shearing rates, correlation rates, and decorrelation times in the edge region are examined with the high-sensitivity 2D beam emission spectroscopy diagnostic on DIII-D. Poloidal flow shear in the turbulence is found to increase in all cases as the transition is approached. As the injected torque is varied from co-current to balanced, a bi-modal structure and strongly dispersive turbulence spectrum develops. At low-rotation this bi-modal structure consists of oppositely propagating flows that lead to flow shear rates increasing above the calculated decorrelation rates.

[1]Supported by the US DOE under DE-FG02-89ER53296, DE-FC02-04ER54698, and DE-FG03-01ER54615.

UP8.00047 Toroidal Flow in Tokamak Plasmas[1] , J.D. CALLEN, A.J. COLE, C.C. HEGNA, U. Wisc.-Madison — Many effects influence toroidal flow evolution in tokamak plasmas. Momentum sources and radial diffusion due to axisymmetric neoclassical, paleoclassical and anomalous transport are usually considered. In addition, the toroidal flow can be affected by field errors. Small, non-axisymmetric field errors arise from coil irregularities, active control coils and collective plasma magnetic distortions (e.g., NTMs, RWMs). Resonant field errors cause localized electromagnetic torques near rational surfaces in the plasma, which can lock the plasma to the wall leading to magnetic islands and reduced confinement or disruptions. Their penetration into the plasma is limited by flow-shielding effects; but they can be amplified by the plasma response at high beta. Non-resonant field errors cause magnetic pumping and radial banana drifts, and lead to toroidal flow damping over the entire plasma. Many of these processes can also produce momentum pinch and intrinsic flow effects. This poster will seek to present a coherent picture of all these effects and suggest ways they could be tested and distinguished experimentally.

[1]Supported by the US DOE under DE-FG02-92ER54139.

UP8.00048 Neoclassical Toroidal Viscosity for Low-Density Ohmic Plasmas in DIII-D[1] , A.J. COLE, C.C. HEGNA, J.D. CALLEN, U. Wisc.-Madison, M.J. SCHAFFER, R.J. LA HAYE, GA — A recent model [1] for field error penetration that includes resonant and non-resonant perturbed 3D magnetic fields has for the first time obtained quantitative agreement with empirical scaling studies of the error-field penetration threshold with electron density. Relevance of the new model relies on the error-field induced neoclassical toroidal viscosity (NTV) being comparable to cross-field diffusive viscosity near a resonant surface of interest. The strength and harmonic structure of NTV for low-density ohmic plasmas on DIII-D are determined from intrinsic vacuum error-field data. Preliminary analysis has shown that NTV in DIII-D is dominated by non-resonant modes. We neglect the plasma response in this initial investigation. An effective cross-field momentum transport owing to NTV is determined, for future comparison with possible cross-field momentum transport rates in ohmic discharges.
[1] A.J. Cole, *et al.,* "Effect of Neoclassical Toroidal Viscosity on Error-Field Penetration Thresholds in Tokamak Plasmas," to be published in Phys. Rev. Lett. (2007).

[1]Supported by US DOE under DE-FG02-92ER54139 and DE-FC02-04ER54698.

UP8.00049 Gyrokinetic Theory and Simulation of Angular Momentum Transport[1] , R.E. WALTZ, G.M. STAEBLER, J. CANDY, F.L. HINTON, General Atomics — A gyrokinetic theory of turbulent toroidal angular momentum transport as well as modifications to neoclassical poloidal rotation from turbulence is formulated starting from the fundamental six-dimensional kinetic equation. GyroBohm-scaled transport is evaluated from toroidal gyrokinetic simulations using the GYRO code [1]. The simulations quantify the two pinch mechanisms in the radial transport of toroidal angular momentum: the slab geometry ExB shear pinch [2] and the toroidal geometry "coriolis" pinch due to finite parallel velocity [3]. The pinches allow the steady-state null stress (momentum transport) condition required for intrinsic toroidal rotation in heated tokamaks without an internal source of torque [4]. A predicted turbulent shift in the neoclassical poloidal rotation [5] may be significant.
[1] J. Candy and R.E. Waltz, J. Comp. Phys. **186**, 545 (2003).
[2] R.R. Dominguez and G.M. Staebler, Phys. Fluids **B5**, 387 (1993).
[3] A.G. Peeters, et al., Phys. Rev. Lett. **98**, 26503 (2007).
[4] G.M. Staebler, et al., Bull. Am. Phys. Soc. **46**, 221 (2001).
[5] G.M. Staebler, Phys. Plasmas **11**, 1064 (2004).

[1]Supported by US DOE under DE-FG03-95ER54309.

UP8.00050 A New Formulation of the Quasi-linear Transport Theory for the Trapped Gyro Landau Fluid Model[1] , G.M. STAEBLER, J.E. KINSEY, R.E. WALTZ, General Atomics — A quasi-linear model of turbulence evaluates the bilinear fluctuation driven fluxes using linearly unstable eigenmodes. A model for the saturated amplitude of the turbulence is used to complete the flux calculation. It is traditional to normalized the fluxes by the amplitude of the electrostatic potential (phi-norm) induced by the linear eigenmode. This is the formulation used in the GLF23 model and in the recently published Trapped Gyro-Landau Fluid (TGLF) model [1]. The normalization of the fluxes is not unique. A variety of alternate choices for normalization have been tested with a large database (>150 runs) of non-linear gyrokinetic simulations using the GYRO code. It was found that several alternate choices give much better fits to this database than the phi-norm for simple mixing length saturation formulas. Using the modulus of the whole linear eigenvector for the TGLF equations as the norm (v-norm) gives a nearly optimum fit to GYRO. This v-norm version of the model fits both s-alpha and shaped Miller geometries
[1] G.M. Staebler, *et al.,* Phys. Plasma **14**, 055909 (2007).

[1]Supported by the US DOE under DE-FG03-95ER54309.

UP8.00051 Towards a Predictive Pedestal Height Model[1] , P.B. SNYDER, A.W. LEONARD, T.H. OSBORNE, General Atomics, H.R. WILSON, U. of York — The pressure at the top of the edge transport barrier (or "pedestal height") strongly impacts tokamak fusion performance, and first principles prediction of the pedestal height remains an important challenge. While uncertainties remain, MHD stability calculations, accounting for diamagnetic stabilization, have been largely successful in predicting the observed pedestal height, when the barrier width is taken as an input. Studies of the pedestal dependence on power input support this understanding, while providing insight into the mechanisms responsible for setting the edge barrier width. Here, we present and characterize edge MHD stability results, including an updated model of diamagnetic stabilization, and a discussion of the mechanisms which can lead to an apparent power dependence of the pedestal. In addition, we explore initial, simple models for the barrier width. The barrier width models, as well as a combination of the width model with MHD stability calculation to directly predict pedestal height, are compared with an extensive set of observations on the DIII-D tokamak.

[1]Supported by the US DOE under DE-FG03-95ER54309.

UP8.00052 Modeling and Analysis of Phase Contrast Imaging Measurements[1] , J.C. ROST, M. PORKOLAB, J.R. DORRIS, MIT, J. CANDY, K.H. BURRELL, GA — The phase contrast imaging (PCI) diagnostic on DIII-D has been operated in several configurations over its lifetime. The beam path was changed in 2003 from tangential at the midplane LCFS to a path passing through the edge at an angle near 45 degrees and reaching typically r/a=0.8, and the maximum wavenumber has been increased from 7 to 30 cm^{-1}. A synthetic diagnostic (SD) has been created to model all configurations of the PCI by post-processing the output of the GYRO gyrokinetic simulation. The SD includes line integration along the full path and models the detector to obtain the high- and low-k cutoffs. Modeling of a plasma discharge typical of DIII-D is used to interpret the PCI spectra $S(k_\perp,f)$ in terms of turbulent ballooning modes and local $S(k_r,k_\theta,f)$. This allows us to identify parts of the PCI spectra with different plasma modes (ITG, TEM, ETG), separate effects of Doppler shift and intrinsic mode velocity in the measurement, and improve comparisons with other diagnostics. The SD will contribute to validation of the model through comparison between simulation and experiment.

[1]Supported by US DOE under DE-FG02-94ER54235 and DE-FC02-04ER54698.

UP8.00053 Development of a Synthetic BES Diagnostic for Application to Gyrokinetic Simulations[1] , C. HOLLAND, G.R. TYNAN, UCSD, G.R. MCKEE, M.W. SHAFER, U. Wisc.-Madison, J. CANDY, R.E. WALTZ, GA, R.V. BRAVENEC, U. Texas-Austin — The validation of microturbulence simulations requires the use of synthetic diagnostics to allow "apples-to-apples" comparisons of predicted and measured turbulence characteristics. We report here on progress in the development of a synthetic beam emission spectroscopy (BES) diagnostic for use with the GYRO code, and results from its application to simulations of a steady L-mode DIII-D discharge. Comparisons of simulated and experimentally measured fluctuation amplitudes, frequency spectra, correlation times and lengths will be presented, as well as a comparison of zonal flow fields obtained by time-delay estimation. The impact of increased channel spot size due to finite neutral beam atom excitation lifetimes, and sensitivity of the results to uncertainties in equilibrium profile gradients is also discussed.

[1]Supported by the US DOE under DE-FG02-04ER54758, DE-FG02-89ER53296, DE-FC02-04ER54698, and DE-FG03-97ER54415.

UP8.00054 Localized Measurement of Short Wavelength Plasma Fluctuations Using the DIII-D Phase Contrast Imaging Diagnostic[1] , J.R. DORRIS, J.C. ROST, M. PORKOLAB, MIT, K.H. BURRELL, GA — The DIII-D phase contrast imaging (PCI) turbulence diagnostic measures density fluctuations in two operational configurations: (1) line-integrated over the entire viewing chord, or (2) using a rotating mask system that takes advantage of the vertical variation of the radial magnetic field to make localized measurements along the PCI chord. The localized length of chord is inversely proportional to wavenumber, making this technique more favorable for short wavelength modes ($k > 15$/cm). In 2006, the PCI S/N was improved by an order of magnitude by a redesigned data transmission system based on fiber optic links. This allowed measurements to be obtained showing broadband turbulent fluctuations to 20/cm. Rigorous analysis of such a localized measurement requires accurate modeling of the focused laser diffraction through the thin masking slit. Recent calibrations successfully validated our model and results will be presented. Measured evolution of turbulence will be characterized in terms of changes in global plasma parameters.

[1]Supported by the US DOE under DE-FG02-94ER54235 and DE-FC02-04ER54698.

UP8.00055 Time-dependent Radial Transport of Electron Distributions Due to ECCD in DIII-D[1] , R.W. HARVEY, A.P. SMIRNOV, CompX, R. PRATER, C.C. PETTY, General Atomics — The radial transport modeling capability in the CQL3D bounce-averaged Fokker-Planck collisional-rf quasilinear code[1] has been greatly improved and the self-consistent time-dependent toroidal electric field added, making the code truly a "Fokker-Planck-Transport" code. The time-dependent, coupled 3D Fokker-Planck equation and the Ampere-Faraday Law equation are solved for the electron distribution, $f(u, \theta_u, \rho, t)$, and the toroidal loop voltage, $V_{loop}(\rho, t)$. A fully 3D, time-implicit solution of the FP equation using sparse-matrix methods[2] is coupled to a new iterative toroidal electric field solve. The DIII-D ECH experiment is in an intermediate driven regime with $\tau_{transport} \approx \tau_{slowing}$[3] for the EC driven electrons. Results will be reported for time-evolution of radial profiles of current density, fast electrons, and toroidal loop voltage due to EC heating and current drive in DIII-D. [1] R.W. Harvey and M.G. McCoy, IAEA TCM on Advances in Simulation and Modeling of Thermonuclear Plasmas, Montreal, 1992; USDOC NTIS No. 93002962. [2] Y. Peysson *et al.*, Radio Frequency Power in Plasmas, 15th Topical Conference, Moran, Wyoming (2003). [3] R.W. Harvey *et al.*, Phys. Rev. Lett. 88, 205001 (2002).

[1]Work supported by USDOE Grant DE-FG02-04ER54744.

UP8.00056 Doppler Reflectometry Measurements of Medium Wavenumber Density Fluctuations and Zonal Flows in DIII-D[1] , L. SCHMITZ, G. WANG, A.E. WHITE, J. JUSTINIANO, T.L. RHODES, W.A. PEEBLES, UCLA — Doppler reflectometry is a versatile diagnostic for poloidal plasma flow measurements and local density fluctuation spectra. Depending on the launch angle and frequency of the probing beam, the signal back-scattered from the plasma cut-off layer is sensitive to density fluctuations at a specific poloidal wavenumber k_θ (3 cm$^{-1} <$ $k_\_ <$ 9 cm^{-1}, calculated using GENRAY ray tracing code). The plasma flow velocity v_θ is obtained with high time resolution from the Doppler shift ω_D of the back-scattered signal ($v_\theta = \omega_D/k_\theta$). Doppler reflectometry is well-suited for the detection of zonal flows, characterized by poloidal flow fluctuations ($v_\theta = k_r\Phi/B_\phi$). Zonal flows are thought to regulate the local turbulence level and radial correlation. We present first reflectometry measurements of geodesic acoustic modes (GAMs) and low frequency zonal flows in DIII-D Lmode plasmas ($0.6 < r/a < 0.9$). The interaction of these time-dependent plasma flows with medium wavenumber density fluctuations is investigated in order to study turbulence self-organization.

[1]Supported by US DOE under DE-FG03-01ER54615 and DE-FC02-04ER54698.

UP8.00057 Radial Correlation Length of Density Fluctuations in DIII-D Plasmas[1] , G. WANG, W.A. PEEBLES, T.L. RHODES, E.J. DOYLE, L. SCHMITZ, A.E. WHITE, L. ZENG, UCLA, R. NAZIKIAN, PPPL, G.R. MCKEE, U. Wisc. — The radial correlation length (L_r) of density fluctuations, which is directly related to the radial scale length of the fluctuations, is an important quantity for understanding turbulent transport in tokamak plasmas. In DIII-D, recent upgrades of the UCLA correlation reflectometer system allow high spatial resolution L_r measurement in both low and high density gradient regions. Initial observations is presented, including: (1) In the OH plasma core, $L_r$decreases as major radius increases, but inferred radial fluctuation scale length $k_r\rho_s$ (ρ_s is the ion gyroradius using T_e and $k_r = 2/L_r$ for a Gaussian radial correlation length) increases outwards; (2) In the plasma core, $k_r\rho_s$ of the L-mode, QH-mode, and hybrid steady-state H-mode are comparable, and more than 2-3 times bigger than those in OH plasmas; (3) In both L- and QH-mode core, little change was observed in L_r as plasma rotation is varied significantly by NB torque change. Initial results from H-mode edge pedestal will also be presented.

[1]Supported by the US DOE under DE-FG03-01ER54615, DE-AC02- 76CH03073, and DE-FG02-89ER53296.

UP8.00058 ITG and TEM Turbulence in DIII-D L-mode Discharges[1] , J.C. DEBOO, C.C. PETTY, G.M. STAEBLER, General Atomics, E.J. DOYLE, T.L. RHODES, L. SCHMITZ, G. WANG, A.E. WHITE, UCLA, G.R. MCKEE, U. Wisc.-Madison — An experiment has been designed to discriminate between the effects of ion temperature gradient (ITG) and trapped electron mode (TEM) turbulence by creating discharges where one of these modes is clearly dominant. With the aid of the GKS and TGLF linear gyrokinetic stability codes, a low-density L-mode target discharge with electron cyclotron heating has been identified where TEM modes are calculated to dominate. By replacing electron cyclotron heating power with neutral beam power, ITG modes are expected to become dominant. The TEM threshold condition will also be tested by varying the local electron temperature gradient scale length to values above and below the threshold condition by employing modulated ECH near the plasma mid-radius. Results of the experiment, including comparison of turbulence measurements at low (ITG) and intermediate (TEM) wavenumbers with gyrokinetic stability code predictions of drift wave spectra and threshold predictions, will be shown.

[1]Supported by the US DOE under DE-FC02-04ER54698, DE-FG03-01ER54615, and DE-FG89ER53296.

UP8.00059 Rational-q Triggered Transport Changes With Varying Toroidal Rotation in DIII-D[1] , M.E. AUSTIN, U. Texas-Austin, K.H. BURRELL, R.E. WALTZ, M.A. VAN ZEELAND, GA, G.R. MCKEE, M.W. SHAFER, U. Wisc., T.L. RHODES, UCLA — Comparison of rational-q triggered ITBs in discharges with varying toroidal torque injection was carried out. Experiments were conducted in negative central shear discharges with different mixes of co/counter neutral beam injection (NBI) that altered the equilibrium ExB shear in conditions where transient improvements in transport occur near integer q_{min} values. The transport changes were seen in high and low rotation cases; however, the latter discharges did not transition to improved core confinement. Observations support the model that sufficient background ExB shear is required for barrier formation and zonal flow effects at integer q_{min} act as trigger in this case. The lack of TAE modes in the balanced injection cases indicates they are not linked to the transient confinement improvement. Fluctuation data obtained in co and balanced NBI show similar reductions in turbulence near integer q_{min} as well as poloidal velocity excursions that may be further evidence of zonal flow.

[1]Supported by US DOE under DE-FG03-97ER54415, DE-FC02-04ER54698, and DE-FG03-01ER54615.

UP8.00060 TURBULENCE AND TRANSPORT —

UP8.00061 Density profile behavior in JET and extrapolations to ITER

MIKHAIL MASLOV, HENRI WEISEN, CRPP, CLEMENTE ANGIONI, IPP Garching, JET-EFDA CONTRIBUTORS COLLABORATION[1] — A growing number of experiments on different tokamaks show that the neoclassical pinch and fuelling by edge neutrals or NBI is generally not able to explain the observed density profiles. Anomalous inward convection appears to be ubiquitous, leading to peaked density profiles at low collisionality in H-modes. Extrapolation to ITER conditions leads to high density peaking for the reference scenario which increases expected fusion gain from Q=10 to Q=30 [1,2]. A comprehensive study of JET experiments of C15-C19 campaigns (2006-2007) was done. Several hundred of density profiles in stationary H-mode phases were analyzed and the scaling law for the density peaking was derived. General agreement with the previous observations [1] was found as well as some new features arise. Effective collisionality still has the highest correlation with density peaking but on the new data one can see a dramatic change of the density profile behavior around ν_{eff} ~0.4. Density peaking increases much faster at lower collisionalities and li correlation appears also. [1] H. Weisen et al. 21st IAEA FEC, Chengdu, China [2] V. Mukhovatov et al. Nucl. Fus.43 (2003)942

[1]See the Appendix of M.L.Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006)

UP8.00062 Characteristics of Zonal Flows in the HL-2A and HT-7 tokamaks[1]

T. LAN, A.D. LIU, C.X. YU, USTC, China, L.W. YAN, W.Y. HONG, K.J. ZHAO, J.Q. DONG, J. QIAN, J. CHENG, D.L. YU, Q.W. YANG, SWIP, China — Zonal Flows, including low frequency Zonal Flow (LFZF) and geodesic acoustic mode (GAM), have been characterized in the HL-2A and HT-7 tokamaks. The three-dimension wavenumber and frequency spectrum for the GAM has been measured in the HL-2A tokamak for the first time. The poloidal and toroidal wave number spectra are peaked sharply at$k_\theta = k_\phi \simeq 0$, while the radial spectrum shows a strong peak at $k_r\rho_i \approx 0.04 - 0.09$ with a width$\Delta(k_r\rho_i) \approx 0.03 - 0.07$. The whole spectral characters of LFZF in both tokamaks are firstly presented here. Bispectral analysis, nonlinear energy transfer and experimental studies on the GAM interaction with turbulence reveal that the parametric instability is a mechanism contributing to the generating of the GAM. Wavenumber mismatch estimation, denoting the coupling of nonlinear three-wave interactions, shows that the resonance conditions are satisfied exactly at the region with highest auto-bicoherency. The turbulent transport related to GAM has been studied in HL-2A tokamak and the results are reported.

[1]Supported by NSFC under Grants 10335060 and 10235010 and Education Ministry of China under Grant 20060358059.

UP8.00063 Improved core confinement in JET plasmas close to q=1 and possible alternative explanations

FLAVIO CRISANTI, ENEA, JET EFDA CONTRIBUTORS* COLLABORATION — Associazione Euratom/ENEA sulla Fusione, Frascati, C.P. 65, 00044 Frascati, Italy In some experiments [e.g. 1,2] internal transport barriers are seen in situations where the usual theoretical pictures do not provide an obvious explanation, e.g. the hybrid regime, with q0 close to 1, or even in the presence of sawteeth. In some cases these events are transient, only affecting the ion channel. However, in some JET experiments enhanced temperature gradients have been observed on both electron and ions lasting about 5s (over 20 energy confinement times and about 1 resistive time). Up to 25% of the ion population were fast particles, providing up to 40% of the plasma stored energy. Similar discharges with higher density did not show the same behavior. The fast ion population, which is sensitive to the density, can stabilize ITG modes [2]. The JET experimental evidence will be analyzed within this theoretical frame and the results compared with other theoretical approaches.
*See the Appendix of M L Watkins *et al.*, Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006)

[1] F Crisanti *et al*, *ibid*
[2] G Tardini *et al.*, Nucl. Fusion **47** (2007) 280

UP8.00064 Effects of kinetic electrons on Alfvenic ITG in global electromagnetic gyrokinetic particle simulations

Y. NISHIMURA, Z. LIN, L. CHEN, UC-Irvine — Employing an electromagnetic gyrokinetic simulation model[1] in a global tokamak geometry,[2] trapped electron effects on the finite beta ITG modes are investigated. With the fluid-kinetic hybrid electron model,[1] non-adiabatic kinetic electrons are perturbatively added on top of the adiabatic fluid electrons. Details on the formulation and the implementation of the electron drift kinetic equation is discussed. This work is supported by U.S. Department of Energy, Cooperative Agreement DE-FC02-04ER54796 and 06ER54860, and in part by SciDAC Center for Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas and Center for Plasma Edge Simulation.

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UP8.00065 Determination of fractional transport exponents in a simple fluid drift-wave turbulence model

DEBASMITA SAMADDAR, D.E. NEWMAN, Univ. of Alaska Fairbanks, R. SANCHEZ, Oak Ridge National Laboratory, B.A. CARRERAS, BACV Solutions Inc. — In this poster, the recently developed nonlocal (quasi-linear) renormalization scheme to derive renormalized transport equations for passive scalars in terms of fractional differential operators will be used to explore transport in a simple drift wave model. In this contribution, we use this new method to determine the existence of fractional exponents in simulations of drift-wave turbulence in slab geometry and discuss the merits and disadvantages of the method with respect to the average propagator method. Several driven and non-driven situations will be explored, in which the relative dominance of the polarization and ExB nolinearities will be tuned artificially. In this way, we also test the robustness of the fractional transport models to changes in the basic dynamics, which will help to assess the potential for application to more realistic geometries of these methods.

UP8.00066 Characterization of transport dynamics from the self-consistent interaction between fluctuations and zonal flows in ITG gyro-kinetic simulations with the UCAN code

D.E. NEWMAN, Univ. of Alaska Fairbanks, R. SANCHEZ, Oak Ridge National Laboratory, J.N. LEBOEUF, JNL Scientific, Casa Grande, AZ, V.K. DECYK , UCLA , Los Angeles, CA, B.A. CARRERAS, BACV Solutions, Oak Ridge, TN — In this poster, we will describe the application of several tools imported from the theory of non-Markovian, non-local stochastic processes to the characterization of the transport dynamics that emerge from the self-consistent interaction of fluctuations and zonal flows in ion-temperature-gradient (ITG) turbulence. The simulations have been performed using the delta-f, PIC gyrokinetic UCAN code. In order to fully understand the implications of the analysis, the results from the self-consistent case will be carefully compared with two additional ITG simulations performed with UCAN using identical parameters. First, one in which the feedback action on the fluctuations carried out by the zonal flows is artificially suppressed. Secondly, a case in which in addition to suppressing the zonal flows, an externally driven flows interacts with the fluctuations.

UP8.00067 Particle characterization of transport in global gyrokinetic calculations of ion channel turbulence in tokamak plasmas[1] , JEAN-NOEL LEBOEUF, JNL Scientific, BENJAMIN CARRERAS, BACV Solutions, VIKTOR DECYK, UCLA, DAVID NEWMAN, University of Alaska at Fairbanks, RAUL SANCHEZ, ORNL — We are in the process of characterizing transport in gyrokinetic calculations of ion channel turbulence in tokamak plasmas with the three-dimensional global toroidal nonlinear parallel particle-in-cell UCAN code. In particular, we have extended the particle manager in UCLA's own PLIB library of massively parallel particle and field managing MPI routines to automatically handle tracking/tracing of the same active simulation particles through space and time and especially multiple processors. The particle data thus tracked and stored comprise the complete set of positions and velocities for each tracked particle at each chosen instant of time (typically every 100th time step). These particle data have been analyzed with tools previously applied to passive marker particles in fluid turbulence simulations which are specifically aimed at revealing the non-diffusive aspects of particle and heat transport. The transport characteristics from UCAN calculations without and with zonal flows self-consistently generated from the fluctuations allowed to evolve will be presented.

[1]Work supported by USDOE

UP8.00068 A turbulent dynamo: Generation of zonal magnetic fields by finite beta drift-ballooning modes in tokamak plasmas[1] , ROBERT KLEVA, PARVEZ GUZDAR, IREAP, University of Maryland, College Park, MD, USA — The generation of zonal flows and zonal magnetic fields can play a significant role in regulating the transport in the edge region of tokamaks. In recent years the focus has been on zonal flows since they are believed to be responsible for initiating good confined modes observed in a variety of magnetic confinement devices. Here we address the generation and saturation of zonal magnetic fields by numerically solving a set of reduced Braginskii equations in a flux-tube geometry. It is shown that the dynamo action leads to the generation of these fields which yields a time-dependent saturated state in which the turbulent drive balances the classical resistivity. The magnitude of the zonal field is however quite small compared to the zonal flow. We will make comparisons from our simulations with recent measurements of zonal fields.

[1]Work supported by DOE

UP8.00069 Electron transport analysis in TCV , WENDELL HORTON, JUHYUNG KIM, Institute for Fusion Studies, University of Texas at Austin, ELINA ASP, L. PORTE, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas Association Euratom-Confederation Suisse, CH-1015 Lausanne — We have investigated the turbulent electron transport in the four current H-mode phases of the TCV discharge 29892 with high-power ECH heating. On ion inertial length scale, we break down the dynamics into collisionless wave, collisional drift wave and trapped electron mode(TEM) (Horton, Phys. Fluids 19, 711, 1976). The transition from drift wave to trapped electron mode is observed in our calculations, and the electron temperature gradient destabilizes the TEM. We find that at the mid-radius, the TEM growth rate are strongly dependent on the collisionality whereas at the outer region, no collisionality dependence is observed. we also analyze the ETG transport with well-known theory based χ_e-models. Finally we show quasi-2D pseudo spectrum simulations for several (r,t) points and time slices for the TEM model and the ETG model. Comparison suggests that the ETG mode is a better candidate for the electron transport in the TCV discharge.

UP8.00070 Drift-Waves and Stability in the GAMMA-10 , J. PRATT, W. HORTON, UT Austin — The tandem mirror system has achieved high energy confinement times ($70-90$ ms) and radial-loss times that dominate the Pastukhov end-loss time (> 100 ms). This high confinement regime establishes a proof of principle that the combination of electrostatic and mirror confinement can successfully insulate electrons from thermal end losses. For the first time, the stored plasma energy of the ions within the plug-barrier end cells exceeds that of the central-cell magnetically-trapped ions. Tandem mirrors exhibit a qualitatively different type of drift-wave transport than do toroidal devices, as we have shown by developing confinement time scaling predictions (J. Pratt and W. Horton, Phys. Plasmas (13), 2006). We analyze electrostatic drift-wave eigenmodes for the electrostatic potential and the magnetic perturbation in the GAMMA-10. Using teraFLOPS-speed, large-scale parallel computers, we then integrate particle orbits in these eigenmode fields.

UP8.00071 Pinch effect and chaotic motion in toroidal confinement devices , G. SPIZZO, Consorzio RFX, Padova - Italy, R.B. WHITE, Plasma Physics Laboratory, P.O.Box 451, Princeton, NJ 08543, S. CAPPELLO, Consorzio RFX, Padova - Italy — Particle transport in a toroidal plasma confinement device can be non-diffusive when magnetic chaos is present but the system is not too far above the stochastic threshold. In some conditions a phenomenological fit to density and impurity profiles gives a diffusion coefficient and also a pinch effect[1]. We show that the combination of diffusion and pinch is an expression of the subdiffusive and nonlocal nature of the transport, brought about by the existence of a spectrum of long distance Lévy flights. The effect is illustrated by numerical modelling of magnetic structure and particle transport in conditions relevant for the reversed-field pinch experiment at the Consorzio RFX. Simulations consist of guiding center calculations of particle motion in the spectrum of MHD modes given by the 3D code SpeCyl[2], and in integration of the Montroll equation[3] with a kernel derived from the simulations, distinguishing between trapped and passing particles. Results are relevant for other systems with chaos induced transport, e.g. electron transport in Tokamaks.

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UP8.00072 Correlation Between Accretion Theory and Spontaneous Rotation Experiments* , M. LANDREMAN, B. COPPI, C. DI SANZO, M.I.T. — The main observations that are consistent with the accretion theory [1] of the spontaneous rotation phenomenon include: i) the reversal of the direction of rotation in the transition from the L- to the H confinement regime that is attributed, by the theory, to the inversion of the phase velocity direction of ballooning modes excited at the edge of the plasma column; ii) the propagation of angular momentum from the outer edge toward the center of the plasma column during the L-H transition; iii) the strong effects of the magnetic field topology of the outermost magnetic surfaces and of the edge plasma regimes on the magnitude and direction of the spontaneous rotation; and iv) the intrinsic connection between spontaneous rotation and the plasma transport properties. The transition in the phase velocity direction of the considered modes is related to that which led [2] to the first experimental identification of collisional drift modes by a (linear) Q-machine where the transition marked the switch-off and on of modes with different mode numbers. A quantitative analysis of the factors that enter the application of the theory to current experiments (e.g. Alcator C-Mod) is given and the developments that this involves are discussed. *Sponsored in part by the US D.O.E. and the N.S.F.
[1] B. Coppi, Nucl. Fus. **42**, 1 (2002)
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UP8.00073 Confinement Regime Transition: Spontaneous Rotation Reversal and Collisionality of the Plasma Edge* , C. DI SANZO, B. COPPI, M. LANDREMAN, M.I.T. — Within the context of the accretion theory [1] of the spontaneous rotation phenomenon, the transition between the L and the H confinement regimes is associated with the reversal of the phase velocity of collisional ballooning modes that can be excited at the edge of the plasma column. These modes are driven by the combined effects of the plasma pressure gradient and the magnetic field curvature, and involve in an essential way the electron-ion and ion-neutral collision rates and the effective transverse (concerning poloidal perturbed velocities) ion viscosity. According to the accretion theory the modes eject plasma angular momentum in the same direction as that of their phase velocity. When the edge is weakly collisional and characterized by local sharp density gradients (as in the H-regime) the mode rotates in the direction of the electron diamagnetic velocity. Under the opposite conditions (L-mode) the phase velocity is in the reverse direction and the consequent recoil causes the plasma column to rotate in the electron diamagnetic velocity direction. It is argued that the quality of confinement is associated with the rate of expulsion of angular momentum. A new resistive electrostatic mode that is driven by gradients of the ion pressure and of the longitudinal flow velocity has been found. *Sponsored in part by the US D.O.E. and the N.S.F.

[1] B. Coppi, Nucl. Fus. **42**, 1 (2002)

UP8.00074 Gyrokinetic turbulence and transport with kinetic electrons in NSTX plasmas , W.X. WANG, S. ETHIER, T.S. HAHM, S.M. KAYE, W.W. LEE, J. MANICKAM, G. REWOLDT, W.M. TANG, Princeton Plasma Physics Laboratory, Princeton, NJ 08543 — Nonlinear gyrokinetic turbulence simulations for shaped plasmas have shown that ITG driven turbulence, even without the supression due to the equilibrium shear flow, drives insignificant ion energy transport in NSTX (about the the neoclassical level). This distinct feature is in contrast to the anomalous transport level for DIII-D simulations, where ITG turbulence is shown to drive a high level of transport (10 × neoclassicallevel), even though the mean turbulence fluctuation amplitude for these two machines are actually comparable. This remarkable difference in turbulent transport properties is further investigated by taking into account the effects of kinetic electrons. Here, full electron dynamics is simulated using the split-weight scheme in our new global simulation code. The equilibrium EXB shear flow is shown not to completely suppress the fluctuations in the well-developed nonlinear turbulence regime while it can stabilize ITG instability linearly. Also reported are our ITG/TEM simulations of NSTX and DIII-D discharges with the focus on energy loss through the electron channel and the comparison of the nonlinearly saturated k-spectra with the experimental measurements. This work was supported by U.S. DOE Contract DE-AC02-76-CH03073 and the SciDAC GPS Center.

UP8.00075 A New Split-Weight Scheme for Finite-β Gyrokinetic Plasmas , W.W. LEE, E.A. STARTSEV, W.X. WANG, Princeton Plasma Physics Laboratory, Princeton, NJ 08543 — The original split-weight scheme for finite-β simulations [1], which separates the perturbed particle distribution into an adiabatic part and a non-adiabatic part, is generalized to include spatial inhomogeneities. The new scheme requires an additional separation of the fast particle response associated with quasi-static bending of the magnetic field lines. While the original scheme follows the non-adiabatic response, δh, in time, where $\delta h = F - (1+\psi)F_0$, F is the distribution, F_0 is the background, $\psi \equiv \phi + \int(\partial A_\parallel/\partial t)dx_\parallel/c$ and ϕ and $A_\parallel$ are the perturbed potentials, the new scheme makes use of $\hat{\mathbf{b}}\cdot\nabla(F_0+\delta g)=0$, where $\hat{\mathbf{b}} = \hat{\mathbf{b}}_0 + \delta\mathbf{B}/B_0$, and further separates the plasma response as $F = (1+\psi)F_0 + \delta g + \delta h$, where $\delta g = \int dx_{||}\kappa\cdot(\nabla A_{||}\times\hat{\mathbf{b}}_0)$ and κ is the zeroth order spatial inhomogeneity. The new δh is again followed in time. The results for finite-β stabilization of drift waves and ion temperature gradient modes in slab geometry using the new scheme with a $\beta(\equiv c_s^2/v_A^2)$ as high as 10% and a grid size of the order of the electron skin depth, are in agreement with those discussed in Refs. [2] and [3]. This work is supported by the DoE OASCR Multi-Scale Gyrokinetics (MSG) Project. [1] W. W. Lee, J. Lewandowski, Z. Lin and T. S. Hahm, Phys. Plasmas **8**, 4435 (2001). [2] J. V. W. Reynders, Ph. D. Thesis, Princeton University (1992). [3] J. C. Cummings, Ph. D. Thesis, Princeton University (1995).

UP8.00076 Nonlocal Neoclassical Calculation of Toroidal Momentum Transport[1] , G. REWOLDT, W.X. WANG, M. BELL, S. KAYE, W. SOLOMON, R. NAZIKIAN, Princeton Plasma Physics Lab — Motivated by experimental observations, neoclassical equilibrium and transport have been studied using global particle simulations by the GTC-Neo code. First, the toroidal angular momentum transport due to collisional dissipation has been calculated to understand whether the spontaneous toroidal rotation observed in plasmas without external momentum sources implies any anomalous momentum transport and torque. In some cases, GTC-Neo calculates that the toroidal momentum diffusivity is 5-6 times larger than previous predictions. Second, simulations of low aspect-ratio plasmas in NSTX show that there is considerable variation of T_i on a magnetic surface, with up to a 20% difference in T_i between the outer and inner sides on the mid-plane. As a consequence, plasma temperature iso-surfaces are shifted from magnetic surfaces. This finite-orbit-width toroidal effect is enhanced as the ratio of ion orbit width to temperature gradient scale length is increased, but is insensitive to the density gradient. The dependence on machine parameters, plasma rotation and collisionality have also been studied. Third, simulations have been made of the poloidal momentum transport to help understand the origin of the "anomalous" poloidal flow observed in DIII-D.

[1]This work supported by U.S. DOE Contract # DE-AC02-76CH03073.

UP8.00077 Low-q resonances, transport barriers, and secondary electrostatic convective cells , CHRIS MCDEVITT, PATRICK DIAMOND, U.C.S.D. — Recent experimental observations have suggested key characteristics of ITB formation near low-q surfaces in off- axis minimum-q (OAMq) discharges. These observations identify mean profile flattening localized to the low-q surface as a transition precursor in the absence of observable magnetic field perturbations. This observation suggests an electrostatic model of ITB formation which accounts for strong transport in the immediate vicinity of the low-q surface, as well as the formation of an ITB nearby the surface. Here, a low-m electrostatic convective cell driven by modulational instability of the background drift wave turbulence is discussed in the context of ITB formation near low-q resonances in OAMq discharges. Unlike pure m=n=0 zonal flows, convective cells are capable of intense mixing near low-q resonant surfaces as well as shearing, thus relaxing mean profiles near the resonant surface. Field line bending coupled with collisional viscosity are found to strongly damp the intensity of the vortical flows except in the case of weak magnetic shear. Furthermore, collisionless convective cell saturation mechanisms such as nonlinear wave trapping are largely circumvented due to the strong mixing of the convective cell. This suggests that low-m convective cells may play a key role in the regulation of turbulent transport near low-q resonances for OAMq discharges. [1] M. E. Austin et. al., Phys Plasmas 13, 082502 (2006)

UP8.00078 Nonlinear excitation and damping of Zonal Flows using a renormalized polarization response , FRED HINTON, PATRICK DIAMOND, University of California, San Diego, La Jolla, CA 92093-0424 USA — The nonlinear interaction of drift-wave turbulence and zonal flows is considered using an analogy with dressed test-particles in a stable plasma. The incoherent mode coupling potentials from the drift waves are treated as a source of noise driving the zonal flows. The coherent mode coupling potentials are included in a renormalized nonlinear polarization response to this noise source, analogous to the shielding of test-particles. The nonlinear damping of zonal flows and the conditions for a steady turbulent state are determined from the nonlinear polarizability. This calculation attempts to systematically address the effects of fluctuations and turbulence on the otherwise 'neoclassical' zonal flow polarization response. Thus it offers the possibility of identifying new nonlinear, kinetic 'channels' for the coupling of zonal flow energy to dissipation. The implications for zonal flow saturation will be discussed. This work was supported by DoE Grant No. DE-FG02-04ER54738.

UP8.00079 Propagation of transport barriers in a simple model of coupled heat and particle fluxes[1] , MIKHAIL MALKOV, PATRICK DIAMOND, University of California San Diego — Understanding of L $\rightarrow$ H transitions is a critical problem in magnetic confinement studies. Strong nonlinearity and coupling of particle and heat fluxes result in solution multiplicity, the L-H mode coexistence. Stationary L $\rightarrow$ H transitions studied in detail earlier reveal the pedestal width to be strictly coupled to the fueling profile in the case of neglected curvature of the pressure profile. Finite pressure curvature, however, shifts emphasis to the heating rate. To better understand the mechanism of L $\rightarrow$ H transitions, particularly factors that determine the pedestal width, we study time evolution of the temperature and density profiles and the L-H interface propagation. Both the inward and outward propagation can occur. It is shown that the heat production in the core region and the fueling at the edge determine the speed and direction of interface propagation. The front propagation solutions describe the penetration of the H-mode state into L-mode state and vice versa. The impact of these findings on the problem of hysteresis of stationary solutions is discussed.

[1]Supported by US DoE.

UP8.00080 Extension of electrostatic gyrokinetics to transport timescales[1] , FELIX I. PARRA, PETER J. CATTO, Plasma Science and Fusion Center, MIT, Cambridge, MA — We outline our efforts to develop an electrostatic nonlinear gyrokinetic full f model that retains transport timescales and determines the electric potential self-consistently. A set of gyrokinetic variables is defined so that the gyrophase dependent part of the distribution is absorbed into the gyrokinetic variables by extending the linear treatment of Ref. [1]. The resulting gyrokinetic equation is valid for wavelengths as small as the ion Larmor radius and allows us to evaluate the gyrophase independent part of the distribution function through order ρ_i/L. When evaluating the potential, the quasineutrality equation usually employed in gyrokinetics may be inadequate for long wavelengths because the terms that determine the potential and zonal flow for short wavelengths become as small as other terms neglected due to limitations of the gyrokinetic equation. Various means of investigating these limitations and suggestions for testing the radial electric field determined from the gyrokinetic and quasineutrality equations will be presented. References: [1] X.S. Lee, J.R. Myra, and Peter J. Catto, Phys. Fluids **26** (1), 1983, 223-229.

[1]Work supported by U.S. DoE and CMPD at U. Maryland.

UP8.00081 Spontaneous Toroidal Rotation in Tokamaks[1] , MALCOLM HAINES, Imperial College London — When two-fluid MHD theory of stability is employed the resulting growth rates are complex, and the perturbing magnetic fields move with a velocity that depends both on the components of the electron drift and heat flux perpendicular to the equilibrium magnetic field and on the diamagnetic velocity. On diffusing into a resistive wall a drag force is exerted on the wall which is proportional to the square-root of the velocity of the perturbing fields. The equal and opposite force or torque will be on the plasma, centred at the singular rational surface for each mode[1]. For typical experimental conditions this leads to a spontaneous, or intrinsic toroidal rotation of 20km/s occurring in a few milliseconds for perturbing magnetic fields of 0.0025tesla. The induced poloidal rotation by this mechanism is generally much larger, but there is considerable poloidal damping due to trapped particles on the ion-ion collision time- scale[2]. Furthermore poloidal angular momentum is in general not conserved for an isolated plasma, and any up-down asymmetry can act as a source or sink[3]; for example, Pfirsch-Schluter diffusion [3 damping by trapped particles[2] and the Ware pinch[4]. [1] J.B.Taylor, Phys.Rev.Lett. 91, 115002 (2003). [2] R.C.Morris, M.G.Haines and R.J.Hastie, Phys.Plasmas 3, 4513 (1996). [3] M.G.Haines, Phys.Rev.Lett. 25, 1480 (1970). [4] M.G.Haines and P.Martin, Phys.Plasmas 3, 4536 (1996).

[1]Contract and discussions at Culham Laboratory are gratefully acknowledged.

UP8.00082 TEQ Free Boundary Equilibrium Solver in TRANSP/PTRANSP[1] , R. ANDRE, D. MCCUNE, PPPL, D. PEARLSTEIN, L. LODESTRO, W.H. MEYER, LLNL — The TRANSP code has traditionally been used to study the results of fusion tokamak experiments. In this mode of operation, the MHD equilibrium is reconstructed inside a prescribed boundary using inverse solvers such as VMEC and ESC. Accurate magnetic field values beyond the plasma boundary are not available. In the PTRANSP project, adding predictive capability to TRANSP, such limitations are overcome by using the free boundary direct solver of TEQ. With this, the poloidal flux on the full (R,Z) grid, the separatrix, and the coil currents can be self-consistently computed. The higher fidelity representation of the field is needed for neutral beam and RF models outside closed flux surfaces and for coupling to edge models. The availability of the TEQ direct solver will also enable options for improvement of the predictive Ohm's law model. This poster will describe the implementation of the TEQ direct solver in TRANSP/PTRANSP and the status of predictive modeling enhancements based thereon.

[1]LLNL work supported by US DOE Contract W-7405-ENG-48.

UP8.00083 Enhancement of NUBEAM for the simulation of fast ion and RF-wave interaction based on the quasi-linear theory , JAE-MIN KWON, NFRC, Korea, DOUGLAS MCCUNE, C.S. CHANG, PPPL — The Monte-Carlo package NUBEAM for time-dependent modeling of fast ions in a tokamak geometry has been upgraded to simulate the effects of ICRF heating on the fast ions. The RF-wave field data is provided by executing TORIC5 inside TRANSP and passed to NUBEAM. An iterative algorithm has been implemented to match the RF-power absorption value calculated by NUBEAM with the level predicted by TORIC5. The effects of RF-wave fields on the fast ions are modeled by evaluating Monte-Carlo kicks based on the quasi-linear theory. Because of the unique feature of NUBEAM, the so called "goosing" which enables an order of magnitude faster calculation, special care needs to be taken in the Monte-Carlo simulation. The modification of the goose algorithm in the presence of RF-wave fields will be presented. Also, the necessary features of NUBEAM for future application to self-consistent coupling with an ICRF full wave code will be discussed.

UP8.00084 TRANSP and PTRANSP at PPPL: Status and Plans. , DOUGLAS MCCUNE, ROB ANDRE, ELIOT FEIBUSH, K. INDIRESHKUMAR, PPPL, JAE-MIN KWON, NFRC, Korea, CHRISTIANE LUDESCHER-FURTH, LEW RANDERSON, PPPL — The PPPL TRANSP code suite is a set of tools for time dependent simulation of tokamak plasmas. The entire system consists of over a million lines of fortran-77, fortran-90, C, and C++ code. Although pieces are over 30 years old, the code has been continually upgraded and modernized, now representing over 60 man-years of labor invested. TRANSP now runs as a service on the Fusion Grid, supporting plasma physics research groups around the world. In this poster, status and plans for TRANSP and associated predictive modeling upgrades (PTRANSP) are summarized. Fusion Grid production system results will be shown. Upgrades to physics models (MHD equilibrium reconstruction, ICRF wave interaction with beam injected fast ions, predictive transport), algorithms (MPI-parallelized source models), and client software (web-browser accessible interactive visualization of run results) will be summarized. The relationship of TRANSP/PTRANSP development efforts to SciDAC and FSP will be discussed. Related posters are cross-referenced.

UP8.00085 PTRANSP Simulations of Sawtooth Oscillations in Tokamak Plasmas , G. BATEMAN, F.D. HALPERN, A.H. KRITZ, A.Y. PANKIN, Lehigh U., R.V. BUDNY, D.C. MCCUNE, PPPL — Simulations with the PTRANSP predictive integrated modeling code are used to investigate sawtooth oscillations in tokamak plasmas. Components of the Porcelli model, the PORCELLI and KDSAW modules available in the NTCC Module Library http://w3.pppl.gov/NTCC, are implemented and used in the PTRANSP code to trigger sawtooth crashes and to reset plasma profiles within the sawtooth mixing radius duringing each sawtooth crash. The H-mode pedestal height is computed using the NTCC PEDESTAL module. Electron thermal, ion thermal, and momentum transport are computed using the GLF23 or the Multi-Mode anomalous transport models, together with neoclassical transport computed using the NCLASS model. The sawtooth model is calibrated by adjusting the magnetic reconnection fraction as well as coefficients in the model. This is accomplished by comparing the sawtooth period and amplitude with experimental data. The effects of sawtooth crashes on fast ion heating profiles, toroidal momentum profiles, as well as electron and ion temperature profiles are investigated. The calibrated simulation protocol is used to investigate the effect of sawtooth oscillations in ITER H-mode discharges.

UP8.00086 PTRANSP Simulations of Toroidal Momentum Transport in Neutral Beam Heated Tokamak Plasmas , F.D. HALPERN, G. BATEMAN, A.H. KRITZ, A.Y. PANKIN, Lehigh U., R.V. BUDNY, D.C. MCCUNE, PPPL — The PTRANSP code is used to predict self-consistently the toroidal rotational frequency, electron temperature, ion temperature, and $\mathbf{E} \times \mathbf{B}$ flow shear rate. Turbulence-driven thermal transport and toroidal momentum transport are computed using several transport models. A neoclassical contribution is added to the turbulence-driven toroidal momentum transport and thermal transport. It is found that inward fluxes of momentum can be generated by the Reynolds stress in the Weiland transport model. The neutral beam injection torque input, computed using the NUBEAM code, drives rotation in the plasma core, while charge exchange can drive rotation near the plasma edge. The poloidal velocity is computed using neoclassical theory. In H-mode discharges, it is found that the largest contribution to the $\mathbf{E} \times \mathbf{B}$ flow shear is usually a consequence of toroidal rotation. The rotation frequency is investigated as a function of plasma parameters including the torque per particle. The simulated radial profiles of the toroidal rotational frequency, ion temperature, and electron temperature are compared with experimental data.

UP8.00087 PLASMA SOURCES, SHEATHS, AND THRUSTERS —

UP8.00088 Modeling and experiments in argon-oxygen rf ICP pulse plasma.[1] , VLADIMIR DEMIDOV, UES, inc, EVGENY BOGDANOV, ANATOLY KUDRYAVTSEV, KONSTANTIN SERDITOV, St. Petersburg State University, CHARLES DEJOSEPH, JR., AFRL — Numerical modeling of an argon-oxygen pulsed discharge (active phase and afterglow) has been performed for a specific device [W. Guo and C. A. DeJoseph, Jr., PSST, 10, 43 (2001)] for a number of experimental conditions. Spatiotemporal behavior of densities of plasma species, as well as fluxes of charged particles including fast electrons, have been calculated. It is demonstrated that in the afterglow of the plasma, production of fast electrons from both electron detachment of oxygen negative ions and from collisions involving argon metastable atoms can be very important. Conditions for self-trapping of these fast electrons have been identified. Measured values of charged particle densities agree reasonably well with calculations. The influence of the presence of the probe on measurements of negative ion densities has been also investigated. A simple method of regulation of negative ion densities and spatial distribution will be presented.

[1]The work has been supported by AFOSR and CRDF.

UP8.00089 Nonlinear kinetic effects in inductively coupled plasmas via particle-in-cell simulations , AARON FROESE, ANDREI SMOLYAKOV, University of Saskatchewan, DMYTRO SYDORENKO, University of Alberta — Kinetic effects in inductively coupled plasmas due to thermal motion of particles modified by self-consistent magnetic fields are studied using a particle-in-cell code. In the low pressure, low frequency regime, electron mean free paths are large relative to device size and the trajectories are strongly curved by the induced rf magnetic field. Analytic linear theories are unable to recover effects accumulated along each nonlinear path. Therefore, the simulated ICP is made progressively more complex to find the source of observed plasma behaviours. With only thermal motion modifying the wave-particle interaction, nonlocal behaviour becomes dominant at low frequencies, causing an anomalous skin effect with increased skin depth and power absorption and decreased ponderomotive force. However, when influenced by magnetic fields, the nonlocal effects are suppressed at large wave amplitudes due to nonlinear trapping. A mechanism is proposed for this low frequency restoration of local behaviour. Finally, a low rate of electron-neutral collisions is found to counteract the nonlinear behaviour, and hence reinforces nonlocal behaviour.

UP8.00090 Design and Construction of the Plasma Bubble Expansion Experiment[1] , Y. ZHANG, A.G. LYNN, University of New Mexico, S.C. HSU, Los Alamos National Laboratory, M. GILMORE, CHRISTOPHER WATTS, University of New Mexico — We will present the design and construction of a new compact coaxial magnetized plasma gun and its associated hardware systems. The plasma gun will be used for experimental studies of "magnetic bubble" expansion into a pre-existing lower density background plasma on the HELCAT facility at UNM. These experiments will address key nonlinear plasma physics issues pertinent to plasma models of the formation and evolution of extra-galactic radio lobes. The gun will be powered by a 120μF 10kV ignitron-switched capacitor bank. High pressure gas, controlled by a gas valve system, will be puffed into an annular gap between inner and outer coaxial electrodes. An applied high voltage ionizes the gas and creates a radial current sheet. The $\sim$ 100kA discharge current generates toroidal flux, and an external magnet will provide poloidal "bias" flux. This poster will describe in detail the design and construction of the various power systems for the new plasma gun source.

[1]Supported by NSF-AST/DOE and LANL LDRD.

UP8.00091 Initial operations of the ALEXIS device with a new, helicon-type rf source[1] , A. EADON, E. TEJERO, E. THOMAS, M. CIANCIOSA, Auburn University — The Auburn Linear EXperiment for Instability Studies (ALEXIS) is a 170 cm long, 10 cm diameter linear magnetized plasma column. Previous investigations [E. Thomas, et al., Phys. Plasmas, 10, 1191 (2003)] on the ALEXIS device have focused on modifications of the radial electric field, which resulted in axial currents and flow shear driven electrostatic ion cyclotron instabilities. Upcoming experiments on the electromagnetic branch of these instabilities require operation under finite beta conditions and current-free plasma generation. To accomplish this, the original filament source was replaced with a helicon-type rf plasma source. This presentation will give initial measurements of the plasma parameters obtained with the rf source and will compare those parameters to those of the filament generated plasmas. Additionally, observations of the low frequency instabilities in the rf generated plasma will be presented.

[1]Supported by US DOE Grant DE-FG02-00ER54476

UP8.00092 Gas Flow Effects on Discharge Characteristics in a Dielectric Barrier Discharge Reactor of Spray Type , WOO SEOK KANG, HYUN-SU KIM, SANG HEE HONG, Seoul National University — The flow characteristic of discharge gas is an essential parameter in spray-type reactors of dielectric barrier discharge (DBD) to control the inside plasma density as well as the radical effluence density outside the reactors toward the work-piece surface in etching or surface treatment processing. To understand the effects of gas flow on reactor operation and plasma property, an experimental and numerical study has been carried out for a parallel-plate narrow-gap DBD reactor of spray-type, which is operated by 10 to 20 kHz sinusoidal voltages to produce argon or helium plasma with an oxygen additive. Varying gas flow rates from 0 to 100 liter/min, the discharge characteristics, such as current-voltage, breakdown voltage, and discharge power, are measured by electrical methods. Distributions of plasma temperature and some radicals ejected along the gas flow direction are estimated by OES diagnostics in both the inside discharge region and the outside radical effluence region. For detailed understanding of radical transport in the effluence area, a simple numerical modeling is developed on the basis of computational fluid dynamics including heat and mass transfer with plasma chemistry, and the calculated results are compared with experimental ones. Finally, the effects of metal surface treatment using the spray- type DBD with different gas flow rates are predicted and compared.

UP8.00093 Nonlocal Control of Plasma Properties in a Pulsed RF ICP in Argon-Oxygen Mixtures , JON BLESSINGTON, West Virginia University Q-Group, CHARLES DEJOSEPH, Air Force Research Laboratory, VLADIMIR DEMIDOV, MARK KOEPKE, West Virginia University Q-Group — Previously [1], we showed that a simple, three-level model could explain the rapid growth of charged particles (measured by probes) following application of rf power to a noble gas. In argon + O2 mixtures, the growth rate of O-atom density is slow compared to the growth rate of the charged particle densities. This growth can be estimated from plasma emission and from numerical modeling of the discharge. As a result, the positive ion density reaches a stationary value much faster than the atomic oxygen density. Thus, by changing the duration of the rf pulse, the ratio of fast electron production, from the reaction O + O- → O2 + e (3.6 eV), compared to the ambipolar flux of positive ions to the discharge walls, can be controlled. This effect can be used for nonlocal regulation of the plasma properties [2].

UP8.00094 Effects of Discharge Current and Gas Flow Rate on CF_4 Abatement Process by Thermal Plasma Decomposition[1] , SOOSEOK CHOI, HYUN SEOK LEE, JUN SEOK NAM, WOO SEOK KANG, SANG HEE HONG, Seoul National University — Perfluorocompounds (PFCs) have been widely used in semiconductor and display industry for wafer etching and chamber cleaning processes. However, it is well known that PFCs are serious global warming gases. Although thermal plasma can efficiently decompose a significant quantity of waste gas, it has demerits of large consumption of electric input power and plasma forming gas in order to commercialize its processes. In this work, effects of arc current and plasma forming gas flow rate on the thermal plasma decomposition process have been experimentally demonstrated and numerically analyzed to improve its economic feasibility. A mixture of 1 % CF_4 and the rest N_2 purging gas of several hundreds slpm was decomposed by nitrogen thermal plasma generated from a plasma torch with hollow electrodes. The input powers were changeable from 40 to 60 kW depending on torch operating conditions for arc currents of 130 through 150 A and plasma gas flow rates of 70 through 90 slpm. At a high current of 150 A and a low gas flow rate of 70 slpm condition, the corresponding input power was about 40 kW and over 96 % of destruction and removal efficiency was achieved for 200 slpm waste gas.

[1]Supported by the Ministry of Commerce, Industry and Energy in Korea.

UP8.00095 Free-floating atmospheric pressure ball plasmas , G.A. WURDEN, C. TICOS, Z. WANG, Los Alamos National Laboratory, C.J. V. WURDEN, Los Alamos High School — A long-lived (0.3 second, 10-20 cm diameter) ball plasma floating in the air above a water surface has been formed and studied in the laboratory. A 0.4 - 1 mF capacitor is charged to 4-5 kV, and subsequently discharged (30-60 Amps, 20-50 msec duration) into central copper cathode held fixed just below the surface of a bucket of water (with a weak solution of various salts in distilled water, such as CuSO4 or CuCl2, LiCl or NaCl). An underwater ring anode completes the circuit. A bubble of hot vapor from the water surface rises up in the first few milliseconds, and changes from a mushroom cloud with stalk, to a detached quasi-spherical object, finally evolving into a vortex ring. The plasma consists of ionized water vapor, with positive salts and OH- radicals, as well as molecular species, and it completely excludes nitrogen or oxygen from the rising plasma structure. A fine boundary layer is visible in orange, in contrast to a green ball interior when using Cu/CuSO4, and filamentary structures are visible at late times. Finally, a whisp of smoke ring is observed as a residue. A variety of visible and infrared imaging (both video and still cameras) are used, along with 200-800 nm time & space resolved spectroscopy, to identify features of this laboratory analog to ball lightning. Possible applications include a windowless ball-plasma powered pulsed copper vapor laser operating at 510 nm.

UP8.00096 Anode Sheath Transition In a Carbon Nanotube Arc Discharge[1] , ABE FETTERMAN, YEVGENY RAITSES, Princeton Plasma Physics Laboratory, MICHAEL KEIDAR, George Washington University — An atmospheric pressure helium arc discharge is used for carbon nanotube synthesis. The arc discharge operates in an anodic mode with the ablating anode made from a graphite material. For such conditions, existing models predict the electron-repelling (negative) anode sheath [1]. In the present experiments, the anode ablation rate is investigated as a function of the anode diameter. It is found that anomalously high ablation occurs for small anode diameters (< 0.4 cm). This result is explained by the formation of an electron-attracting (positive) anode sheath leading to increased power losses on small anodes as compared to larger anodes. The suggested mechanism for the positive anode sheath formation is plasma convergence. The increased ablation rate due to this positive sheath could imply a greater yield of carbon nanotube production.

[1] M. Keidar et al, J. Nanosci. Nanotech.6 (2006) 1309

[1]This work was supported by the US DOE under contract No. DE-AC02-76CH03073

UP8.00097 Disinfection of *S. mutans* Bacteria Using a Plasma Needle at Atmospheric Pressure[1] , S. HANSEN, J. GOREE, BIN LIU, Dept. of Physics & Astronomy, The Univ. of Iowa, D. DRAKE, Dows Institute for Dental Research, Dept. of Endodontics, College of Dentistry, The Univ. of Iowa — The plasma needle device produces a millimeter-size low-power glow discharge at atmospheric-pressure. It is intended for dental or medical applications. Radio-frequency high voltage is applied to a single needle electrode located inside a concentric gas-flow nozzle. A low-speed helium plasma jet flows out of the nozzle and mixes with ambient air. The jet is impinges on a surface that is to be treated, which in our test was a suspension of *S. mutans* bacteria that was plated onto the surface of agar nutrient in a Petri dish. *S. mutans* is the most important microorganism for causing dental caries. Imaging the sample after plasma treatment and incubation reveal the conditions where bacteria are killed, and the size of the treated spot.

[1]supported by an NIH training grant

UP8.00098 Dynamical properties of non-equilibrium atmospheric plasma jets and their applications to plasma processing in liquids , KATSUHISA KITANO, Center for Atomic and Molecular Technologies, Osaka University, Japan, IKAWA SATOSHI, Technology Research Institute of Osaka Prefecture, HITOSHI FURUSHO, Institute of Materials Science, University of Tsukuba, YUKIO NAGASAKI, University of Tsukuba, SATOSHI HAMAGUCHI, Osaka University — Non-equilibrium atmospheric pressure plasma jets are discussed with the emphasis on their physics and applications. Plume-like plasmas, which may be called plasma jets, have been generated in a discharge system consisting of a dielectric/metal tube (through which He gas flows at the atmospheric pressure) and a single electrode attached to the tube, to which low-frequency, high-voltage pulses (∼10kV, ∼10kHz) are applied. With visible light images taken by a high-speed ICCD camera, it has been confirmed that the plasma jet consists of a series of small "plasma bullets" that are emitted intermittently from the powered electrode in sync with the positive voltage pulses. The observed "plasma bullet" may be interpreted as a fast moving ionization front. The plasma jets are energetic enough to generate highly reactive charge-neutral radicals but their gas temperatures remain low. Therefore the plasma jets are ideal for processing of liquid based materials at low temperatures and some examples of process applications, such as reduction of cations, polymerization of liquid monomers, and sterilization, will be also presented.

UP8.00099 High-beta effects in a helicon plasma , ROD BOSWELL, CORMAC CORR, Australian National University, SPACE PLASMA POWER AND PROPULSION TEAM — Above an input power of 900 W and a magnetic field of 30 G in WOMBAT, a 150 cm long 80 cm diameter chamber, a narrow column of bright blue Ar II light with a diameter of $\sim$ 6 cm is observed along the axis of the diffusion chamber. Although the axial plasma density is very uniform, the radial profiles are not, suggesting that a large diamagnetic current might be induced. This has been investigated by measuring the temporal evolution of the magnetic field (B_z) and the plasma kinetic pressure in a pulsed discharge mode. Although the electron pressure can exceed the magnetic field pressure by a factor of 2, a complete expulsion of the magnetic field from the plasma interior is not observed. The magnetic field displays the strongest change at the plasma centre, which corresponds to the maximum in the plasma kinetic pressure. These results can be explained by taking into account the penetration of the magnetic field into the plasma which is faster than the plasma formation time resulting in only a slight perturbation of the magnetic field in the continuous plasma.

UP8.00100 Thermal Phenomena in Gas Confinement Dielectric Tube of the VASIMR Helicon Plasma , DAN BERISFORD, Univ of Texas at Austin, R. BENGTSON, L. RAJA, J. SQUIRE, L. CASSIDY, J. CHAUNCERY, G. MCCASKILL, AD ASTRA ROCKET COMPANY COLLABORATION — A quartz dielectric tube provides gas confinement in the helicon discharge of the VASIMR (Variable Specific Impulse Magnetoplasma Rocket) experiment. Despite highly aligned magnetic field lines to confine the plasma in the discharge, significant thermal heating of the dielectric tube occurs. We perform infrared camera imaging studies of heating of the tube with varying operational parameters of the experiment. Results show decreased heating of the tube as the plasma becomes more highly magnetized and less collisional. The data follows a trend that is well represented by a Bohm transport of ions perpendicular to the magnetic field lines suggesting that ion impact on the tube rather than radiation is the primary heating mechanism. Highly localized heating is also observed directly under the antenna in regions where the coils lie closest to the tube surface. This phenomenon is attributed to capacitive coupling effects that accelerate ions under the antenna coils, increasing the local energy flux to the tube surface.

UP8.00101 On the effect of dc resistance on determination of sheath electron density profiles in collisionless plasmas[1] , DAVID N. WALKER, SFA, Crofton, MD, DAVID D. BLACKWELL, RICHARD F. FERNSLER, WILLIAM E. AMATUCCI, Naval Research Laboratory — In recent work^{+} we examined primarily the high frequency ($\omega_{pe}/2 < \omega < \omega_{pe}$) ac impedance characteristics of a small, negatively-biased, spherical probe immersed in collisionless laboratory plasma. Theoretical solutions indicate that collisionless resistance in the sheath at a given resonant radius is a function of applied frequency and is inversely proportional to the plasma density gradient there, *i.e.*, the gradient is evaluated at the radius where the applied frequency is equal to the plasma frequency. As the calculation nears the probe radius, the gradient increases and the density decreases toward zero causing the ac resistance to vanish in the limit, *i.e.*, $d\omega_{pe}/dr$ approaches a maximum and ω_{pe}, a minimum. However, experiment shows an increasing resistance as the surface is approached and no tendency to exhibit a "cutoff" regardless of bias. We interpret these observations as arising from the dc response of the probe. We present results of experimental studies which include the lower frequency effects.$^{+}$Walker, D.N., R.F. Fernsler, D.D. Blackwell, W.E. Amatucci, S.J. Messer, **Phys. of Plasmas, 13**, 032108 (2006)

[1]Work supported by ONR

UP8.00102 Convective Instabilities and Enhanced Electron Scattering Inherent to Presheaths[1] , S.D. BAALRUD, C.C. HEGNA, J.D. CALLEN, University of Wisconsin-Madison — The stability of a presheath in weakly-collisional unmagnetized plasma with cold ions relative to electrons is analyzed. Ions are treated with the fluid equations and electrons as a collisionless (Vlasov) plasma in our derivation of inherent instabilities that grow due to the presheath electric field and corresponding ion flow. Our model suggests ion acoustic-type instabilities that depend on the local ion fluid speed throughout the presheath for modes with wavelengths typically shorter than the local Debye length. These convective instabilities propagate along the electric field with a growth rate depending upon the non adiabatic electron response. These instabilities produce a long range collective response for discrete particles. A Lenard-Balescu type collision operator is derived that accounts for the convective instabilities and leads to enhanced electron scattering relative to conventional Coulomb scattering and, therefore, modifies the electron distribution function. The presence of convective instabilities may provide an explanation for Langmuir's paradox whereby enhanced electron scattering may lead to populating the otherwise truncated part of the electron distribution function near a plasma boundary.

[1]Work supported under a National Science Foundation Graduate Research Fellowship and US DOE Grant No. DE-FG02-86ER53218

UP8.00103 Exact solution for the generalized Bohm criterion in a two-ion species plasma[1] , DONGSOO LEE, University of Wisconsin-Madison, LUTFI OKSUZ, Suleyman Demirel University, Turkey, NOAH HERSHKOWITZ, University of Wisconsin-Madison — For a weakly collisional two-ion species plasma, it is shown that the minimum phase velocity of ion acoustic waves (IAWs) at the sheath/presheath boundary is equal to twice the phase velocity in the bulk plasma. This condition provides a theoretical basis for the experimental results that each ion species leaves the plasma with a drift velocity equal to the IAW phase velocity in the bulk plasma [1]. It is shown that this result is a consequence of the generalized Bohm criterion and IAW dispersion relation. It is now apparent that the results for weakly collisional two-ion species plasmas are the same as for single-ion species plasmas. In both situations, the ion drift velocity at the sheath/presheath boundary is equal to the bulk ion sound velocity.
[1] D. Lee, G. Severn, and N. Hershkowitz, Appl. Phys. Lett. (accepted for publication).

[1]Work was supported by DOE Grant No. DE-FG02-97ER54437.

UP8.00104 Experimental verification of the Bohm criterion for two species plasmas[1] , NOAH HERSHKOWITZ, University of Wisconsin-Madison, LUTFI OKSUZ, Suleyman Demirel University, Turkey, DONGSOO LEE, University of Wisconsin-Madison — Ion acoustic wave (IAW) phase velocities are measured near the sheath/presheath boundary in weakly collisional argon/xenon plasmas. Wave profiles vs. position are measured using a boxcar averager with a gate of 30 nsec and CW excitation. Variable gate delays allow measurement of details of the wave close to the boundary. It is shown that the phase velocity at the presheath/sheath boundary is approximately twice the phase velocity in the bulk plasma for mixture and single species plasmas. This indicates each ion species drift velocity at the boundary is equal to the IAW phase velocity in the bulk plasma. This result is independent of relative ion concentration.

[1]Work supported by DOE Grant No. DE-FG02-97ER54437.

UP8.00105 Overview of Stanford's Activities in the Development of a Coaxial High Energy Thruster , MARK CAPPELLI, FLAVIO POELMANN, NICOLAS GASCON, Stanford University — This poster gives an overview of Stanford's current efforts in the development of a coaxial gas-fed pulsed plasma accelerator that draws steady state power on the 1 to 10 kW level, but delivers thrust through high power, high density pulses. This Coaxial High ENerGy (CHENG) Thruster operates at number densities on the order of 10^{15} cm^{-3} and process peak input powers of 1 MW over 10 μs pulses. The high specific impulse, high thrust density, low beam divergence and low electrode erosion originally made the Deflagration thruster very attractive for missions to the outer planets and beyond. Stanford is exploring the scalability of this device for possible applications in orbit raising or travel to neighbor planets. The poster gives and overview of experimental work and theoretical models currently being developed at Stanford.

UP8.00106 Investigation of Plasma Potential and Electron Dynamics in the Near-Field of Hall Plasma Thrusters , ANDREW SMITH, MARK CAPPELLI, Stanford University — A 3-D map of the plasma potential in the near-field of a laboratory $E \times B$ Hall thruster has been experimentally obtained. The tested thruster channel spans radially from 35mm to 47mm. The measurements lie within a cubic volume 100mm on a side centered on the central axis of the thruster. The results of a 3-D discrete electron transport simulation are presented for the near-field of the thruster. For a prescribed magnetic and electric field distribution in the near-field, a staggered leapfrog time-integrating method is utilized to track electrons launched from a simulated cathode. Inter-particle collisions and field instabilities are ignored though collisions with surfaces are treated. Spatial maps of the relative electron density, mean electron energy, and estimated local Hall parameter are presented. The model results indicate that measured channel to beam current ratios may be largely governed by the field structure in the near-field, and that the local Hall parameter is anisotropic in the domain with a mean value on the order of 1.

UP8.00107 Effects of sheath instability on plasma properties in a Hall thruster discharge , DMYTRO SYDORENKO, ANDREI SMOLYAKOV, University of Saskatchewan, Saskatoon, SK, Canada, IGOR KAGANOVICH, YEVGENY RAITSES, Princeton Plasma Physics Laboratory, Princeton, NJ, USA — The sheath near the electron-emitting surface may become unstable if it is characterized by the negative current-voltage characteristic, which occurs in presence of strong secondary electron emission. A 1d3v particle-in-cell code is applied to study the sheath instability effects on plasma-wall interaction in Hall thrusters. It is found that in stable stationary plasma state the final phase of cyclotron rotation of secondary electrons emitted from the thruster walls is not arbitrary but belongs to the discrete set of stability intervals [Kaganovich et al., Phys. Plasmas 14, 057104 (2007); Sydorenko et al., submitted to Phys. Plasmas (2007)]. In the limit of high discharge voltages, a new regime with relaxation oscillations is identified. In this regime, the plasma constantly switches between a state with non-space charge limited emission and a state with a space charge limited emission [Sydorenko et al., IEPC-2005-078].

UP8.00108 Characterization of the plasma plume in the current overrun regime of cylindrical Hall thrusters[1] , ERIK M. GRANSTEDT, Princeton University, Y. RAITSES, N.J. FISCH, PPPL — Cylindrical Hall thrusters (HTs)[2] may be more promising than annular HTs for low-power scaling due to a smaller surface-to-volume ratio. High plasma plume divergence is a main drawback to cylindrical HTs as decreased efficiency and spacecraft integration issues may result. Recent measurements of the plume angle show that overrunning the discharge current above its self-sustained value can significantly decrease plume divergence. In this "current-overrun" regime, the half-plume angle of the cylindrical HT was reduced to 55°. Thrust measurements demonstrate that the current-overrun regime can have an anode efficiency of up to 35–40% at 100–200 W discharge power levels: an improvement of over 60%. Measurements of the ion energy distribution function in the plasma plume using a retarding potential analyzer reveal both increased ion current density and ion energy on-axis, indicating that these ions are ionized in a region of higher plasma potential. Also, the average energy of off-axis ions is substantially reduced, resulting in improved performance and lowered risk of damage to spacecraft components.

[1]This work was supported by AFOSR and US DOE under contract No. DE-AC02-76CH03073.
[2]Y. Raitses and N. J. Fisch, *Phys. Plasmas* 8, 2579 (2001)

UP8.00109 Experiments with Non-Self-Sustained Regimes of Hall Thruster Discharge[1] , YEVGENY RAITSES, ARTEM SMIRNOV, ERIK GRANSTEDT, NATHANIEL J. FISCH, PPPL — In conventional Hall thrusters, a steady state cross-field discharge is sustained between the anode and a hollow cathode. The current density at the cathode thermionic emitter is usually large enough to provide sufficient heating for self-sustained operation. It is commonly accepted that the thruster discharge current is limited by ionization of the working gas, wall losses and electron cross-field transport, and not by the electron supply from the cathode. We report that with all thruster parameters unchanged, the discharge current can be increased over and above what is normally required for sustaining the steady state discharge by running an auxiliary discharge between the cathode and an additional electrode [1]. For the cylindrical Hall thruster geometry, such a non-self-sustained operation is characterized by improved plasma plume focusing and higher thrust [1, 2]. These results are analyzed and compared with a conventional annular geometry Hall thruster.
[1] Y. Raitses et al, Appl. Phys. Lett. 90 (2007) 221502
[2] A. Smirnov et al, Phys. Plasmas 14 (2007) 057106

[1]This work was supported by the AFOSR and the US DOE under contract No. DE-AC02-76CH03073

UP8.00110 Ion flows in a two-component expanding plasma , IOANA BILOIU, EARL SCIME, West Virginia University — The Ar and Xe ion velocity distribution functions (ivdfs), determined by laser induced fluorescence (LIF), in the expansion region of a helicon plasma have been measured as a function of ratio of Xe to Ar gas flow rates for a constant total gas flow rate. In the magnetic field gradient region ($\sim$5cm upstream from the helicon source-expansion chamber junction) and at low pressure ($\leq$ 2 mTorr) the Ar ivdf is bimodal with a fast group at a speed of $\sim$ 7 km/s and a slow group at $\sim$ 3.5 km/s. The bimodal structure persists for a wide range of Ar/Xe gas flow ratios, disappearing (due to the lack of LIF signal) at 10% Xe. Increasing Xe partial pressure does not affect the Ar ion flow velocities, but does decrease the Ar LIF amplitude. Conversely, the Xe ivdf is unimodal with a bulk ion flow of 0.85 km/s. To understand the excitation mechanisms of the investigated ion states, electron energy distribution functions were obtained from planar Langmuir probe characteristics by the Druyvestein method. The eedf is sensitive to the gas composition: for 2% Xe, the eedf changes from a single Maxwellian with a temperature of $\sim$ 7.5 eV to a bi-Maxwellian with a cold component at $\sim$ 2.5 eV and a hot component at $\sim$8.5 eV. The effective temperature calculated from eedf integration exhibits a sharp decrease with increasing Xe fraction, down to $\sim$4.5 eV at 40% Xe and is then constant for larger Xe fractions.

Thursday, November 15, 2007 2:00PM - 4:20PM –

Session UM5 Mini-conference on the First Microns of the First Wall: Graphite Wall Sputtering and Evolution Rosen Centre Hotel Salon 11/12

2:00PM UM5.00001 In-situ investigations of material migration in recent JET campaign , A. KRETER, Institut für Energieforschung - Plasmaphysik, Forschungszentrum Jülich, Association EURATOM - FZJ, Trilateral Euregio Cluster, Germany, ON BEHALF OF TFE AND JET EFDA TEAM — To improve understanding of material erosion and migration in view of the planned ITER-like wall in JET, a set of in-situ material migration diagnostics has recently been installed, including quartz microbalance (QMB) systems. These techniques are focused on the identification and the quantification of processes determining the carbon migration by time resolved measurements. Studies across the recent JET 2006-07 campaigns show that the major characteristics of carbon transport in the divertor can be summarised as follows: (i) The transport is mainly line-of-sight, with particles predominately sputtered at the strike point (SP) positions and travelling over distances of up to several centimetres across the magnetic field; (ii) The amount of eroded carbon depends on the surface type. The highest rates are obtained after a shift of the strike-point to the "fresh" layers deposited in previous discharges ("history" effect); (iii) there is a clear non-linear increase of the erosion rates in the inner divertor with increasing ELM energies. This ELM induced erosion is attributed to the thermal decomposition of carbon layers.

2:20PM UM5.00002 Chemical Sputtering of graphite surfaces by slow H and D Atomic and Molecular projectiles[1] , F.W. MEYER, H. ZHANG, H.F. KRAUSE, Physics Division, Oak Ridge National Laboratory — Because of its high thermal conductivity, excellent shock resistance, absence of melting, low activation, and low atomic number, there is significant technological interest in using graphite as a plasma-facing component on present and future fusion devices, despite its poor chemical erosion and sputtering properties. As divertor designs evolve, the interest in the erosion characteristics of the carbon surfaces is shifting to progressively lower impact energies. Results are presented of chemical sputtering yields for ATJ graphite and HOPG impacted by $H^+(D^+)$, $H_2^+(D_2^+)$and $H_3^+(D_3^+)$ in the energy range 5-250 eV/amu. The measurements serve as benchmarks for in house MD simulations [Physica Scripta **T128**, 50 (2007)] of the chemical sputtering process that seek to incorporate more realistic many-body potentials and to expand the reaction pathway to include vibrational and/or electronic excited states. Comparison between same velocity atomic and molecular ion impact at energies as low as 5 eV/amu will be described [J. Nucl. Mater. **357**, 9(2006)]. In addition, the isotope effect in methane production by H and D incident ions will be discussed.

[1]Research supported by the OFES and the OBES of the U.S. DOE under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

2:40PM UM5.00003 MD Simulations of Plasma-Surface Interactions of Deuterated Carbon[1] , P.S. KRSTIC, C.O. REINHOLD, Oak Ridge National Laboratory, S.J. STUART, Clemson University — We study plasma-surface interactions (PSI) in the first few nanometers of carbon walls, at fluences of $\sim 10^{20}$ D m^{-2} and impact energies in range of tens of eV. Using an atomistic classical molecular dynamics (MD) approach we are able to take into account the full configuration space of impact plasma particles (atoms, molecules), including their rovibrational states, as well as to describe with the same level of detail the PSI outcome, i.e. of particles ejected by chemical sputtering and reflection. Understanding of the relevant PSI processes, reflecting the deuterated surface microstructure is obtained [*New J. Phys.* **9**, 209 (2007), *Europhys. Lett.* **77**, 33002 (2007)], as well as a good agreement with recent in-house beam-surface experiments. This increases confidence in our MD calculations for impact of plasma particles distributed at a given temperature. Our results show that the products of the PSI of deuterated carbon are significantly different from those of "pure" carbon, highlighting the importance of accounting for the hydrogen content in the walls.

[1]We acknowledge support by the OFES and the OBES of the U.S. DOE under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC, of SciDac, and (SJS) of DOE (DE-FG02-01ER45889), the NSF (CHE-0239448) and a MURI managed by the ARO.

3:00PM UM5.00004 Structural Studies of Carbon Dust Samples Exposed to NSTX Plasma[1] , YEVGENY RAITSES, CHARLES H. SKINNER, Princeton Plasma Physics Laboratory, FUMING JIANG, THOMAS S. DUFFY, Geosciences, Princeton University, ANGUS PACALA, Stanford University — Raman spectroscopy offers a sensitive measure of the microstructure of carbon dust. We present Raman spectra of dust samples exposed to the NSTX plasma, unexposed dust, carbon deposits produced in an arc discharge, and heat-treated (1500-2000 °C) carbon samples all made from graphite material. The main difference in the measured Raman spectrum is that for the exposed dust samples, the high energy G-mode peak (Raman shift $\sim$1580 cm^{-1}) is much weaker than the defect-induced D-mode peak (Raman shift $\sim$ 1350 cm^{-1}), while for the unexposed samples, similarly to commercial graphite, the ratio of G-mode to D-mode peaks is always larger than 1. These results indicate that the production of carbon dust particles in NSTX involves modifications of the physical and chemical structure of the original graphite and these modifications are similar to those induced by the arc plasma to carbon particles.

[1]This work was supported by the US DOE under contract No. DE-AC02-76CH03073

3:20PM UM5.00005 Hydrogen dynamics under strong plasma-wall coupling[1] , A.YU. PIGAROV, S.I. KRASHENINNIKOV, UCSD, A. PLETZER, Tech-X Corp. — The newly developed time-dependent one-dimensional code WALLPSI for wall temperature and erosion rates as well as for trapped, absorbed, and mobile hydrogen inside the wall is discussed. The code is a part of integrated model FACETS for core/edge/wall transport. To study the basic physic process, the code is coupled to the 1D edge plasma transport code. The results of self-consistent plasma/neutral/wall modelling which show strong plasma-wall coupling are presented. Variation of hydrogen inventory in the wall in response to changing plasma impact is discussed. Thermal instability of plasma in contact with hydrogen saturated wall is analyzed.

[1]Work supported by research grant DE-FG02-04ER54739 at UCSD.

3:40PM UM5.00006 Investigation of Plasma Surface Interactions with the PISCES ELM Laser System , K.R. UMSTADTER, M. BALDWIN, J. HANNA, R. DOERNER, T. LYNCH, T. PALMER, G.R. TYNAN, UCSD — When an ELM occurs in tokamaks, up to 30% of the pedestal energy can be deposited on the wall of the tokamak causing heating & material loss due to sublimation, evaporation and melt splashing of plasma facing components (PFCs) and expansion of the ejected material into the plasma. We have explored heat pulses using an electrical power circuit to draw electrons from the plasma to heat samples ohmically. This system is limited in power to $\sim$250kJ/m^2 at the minimum pulse width of 10ms and depletes the plasma column, complicating spectroscopy. We have completed calculations that indicate that a pulsed laser system can be used to simulate the heat pulse of ELMs. We are integrating laser systems into the existing PFC research program in PISCES, a laboratory facility capable of reproducing plasma-materials interactions expected during normal operation of large tokamaks. Two Nd:YAG lasers capable of delivering up to 50J of energy over various pulsewidths are used for the experiments. Laser heat pulse only, H+/D+ plasma only, and laser+plasma experiments were conducted and initial results indicate that metals behave very differently while exposed to plasma and simultaneous heat pulses. We will also discuss initial results for carbon PFCs and material transport into the plasma. Supported by US DoE grant DE-FG02-07ER-54912.

4:00PM UM5.00007 Atomistic Simulations of Energetic Particle Interactions with the First Wall.[1] , ROGER STOLLER, Oak Ridge National Laboratory — Atomistic simulations of the interactions between energetic particles and a fusion reactor first wall have been carried out using molecular dynamics to investigate both primary damage formation in the structural first wall material and the sputtering of surface atoms which can lead to contamination of the plasma. In the case of damage formation in the structural material, the results provide a quantitative measure of the effect of a nearby free surface on the evolution of atomic displacement cascades, and the nature of the residual damage produced. This damage is characterized by the total number of point defects (vacancies and interstitials), as well as the number and size distribution of point defect clusters produced. A sufficient number of simulations have been completed to statistically evaluate variations between surface-influenced and bulk cascades. Surface sputtering from the molecular dynamics simulations is compared to the results obtained with a more simple, and widely-used Monte Carlo model (SRIM).

[1]Research sponsored by the Division of Materials Sciences and Engineering and the Office of Fusion Energy Sciences, U.S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

Thursday, November 15, 2007 3:00PM - 5:00PM –

Session VI2 Interstellar and Solar Wind Turbulence, and Coronal and Auroral Emissions Rosen Centre Hotel Salon 3/4

3:00PM VI2.00001 Intermittency of Electron Density in Interstellar Kinetic Alfvén Wave Turbulence[1] , P.W. TERRY, University of Wisconsin-Madison — Pulsar radiation pulses broaden as they propagate through interstellar space. The observed scaling of the pulse duration with distance to source indicates that the electron density fluctuations that broaden the pulse do not obey a Gaussian distribution. Instead they obey a Levy distribution, which contains an enhanced power-law tail. The physical mechanisms responsible for this tail remain to be established. We show that a Levy distribution arises from magnetic turbulence near the Larmor-radius scale where electron density actively couples to the magnetic field through kinetic Alfvén wave (KAW) fluctuations. The analysis reveals a new type of turbulent intermittency mediated by compressive effects in electron physics rather than advection. Using analytic theory and computation we show that coherent structures form in the current, magnetic field, and density of decaying KAW turbulence. These structures avoid mixing by the turbulence because they have a strongly sheared magnetic field that refracts turbulence away from them. The required shear places these structures in the tail of the distribution function. Their probability is enhanced because decay by turbulent mixing is suppressed by the refraction. The current structures are localized but Ampere's law and KAW equipartition give coherent density and magnetic field extended spatial envelopes. These envelopes decay as r^{-1} outside the current structure. This structure leads to a probability distribution function with a power-law tail. The probability of density gradient decays as $(\nabla n_e)^{-2}$, a Levy distribution. Because there are laboratory plasmas with magnetic turbulence at the Larmor-radius scale, it should be possible to look for these effects in the laboratory.

[1]In collaboration with K.W. Smith. Supported by NSF.

3:30PM VI2.00002 Turbulence in the Solar Wind: Theory, Simulations, and Comparisons with Observations[1] , GREGORY HOWES, UC Berkeley — *In situ* measurements of the solar wind uniquely enable detailed comparison of turbulence in an astrophysical environment with theory and simulations. We present an analytical cascade model that follows the nonlinear flow of turbulent energy from the large driving scales in the MHD regime to the dissipative scales in the weakly collisional kinetic regime. For a large inertial range, scaling arguments suggest the turbulence remains low frequency, $\omega \ll \Omega_i$, due to the anisotropy of the MHD cascade, $k_\parallel \ll k_\perp$. Such low-frequency, anisotropic turbulence is optimally described by gyrokinetics. In this limit, the MHD Alfvén wave cascade transitions to a kinetic Alfvén wave cascade at the scale of the ion Larmor radius. Analytical cascade model results, nonlinear gyrokinetic simulations, and observational evidence support this claim, eroding the case for the importance of the ion cyclotron resonance in causing the break and steeper dissipation range of the turbulent magnetic energy spectrum in the solar wind. The analytical cascade model predicts that one expects an exponential cut-off in the energy spectrum above the spectral break, but that instrumental sensitivity limitations lend the dissipation range a power-law appearance. The observed variation of dissipation range slopes is naturally explained by the varying effectiveness of Landau damping as the plasma parameters change. Conditions under which the cyclotron resonance may play a role are identified. Nonlinear gyrokinetic simulations of solar wind turbulence support the predictions of the analytical model, producing magnetic and electric field fluctuation spectra that are consistent with satellite measurements.

[1]Supported by the DOE Center for Multi-scale Plasma Dynamics, Fusion Science Center Cooperative Agreement ER54785.

4:00PM VI2.00003 The plasma properties of the solar corona, a detailed interpretation , URI FELDMAN, Artep Inc. 2922 Excelsior Spring Circle, Ellicott City, Columbia MD, and Space Science Division, Naval Research Laboratory, Washington DC — The solar corona is the plasma volume surrounding the 1.5x10^6 km diameter Sun. It consists of numerous structures of various sizes of which some last for days and reach lengths of several solar radii. Having a low electron density (usually $n_e \leq 1\times10^9$ cm^{-3}) the corona is essentially optically thin allowing emission from all structure along a line of sight to reach an observer. When assuming that each coronal structures has its own unique temperature, a value slightly different from that of the rest, it is tempting to assume that the function describing the coronal emission measure vs. temperature ($\int n_e^2 dV$ where n_e is the electron density and dV a volume element along the line of sight) is a monotonically changing function in the 7x10^5-5x10^6 K range. Essentially for the last half century this was the accepted depiction of the coronal condition. Recently, aided by spectra recorded by a high resolution stigmatic spectrometer, we studied in great details the electron temperature and emission measure properties of plasmas between 1.03R$_/$ and 1.5R$_/$ (30,000-450,000 km) and found that the commonly accepted description is lacking. In reality coronal plasmas at such heights are isothermal and could attain but one of only three temperatures, 9x10^5, 1.4x10^6 and 3x10^6 K. Furthermore, we found that in at least the two higher temperature plasma volumes to within the observational uncertainties the electron distribution is Maxwellian. The fraction of super thermal electrons, if present, in the 1.4x10^6 and the 3x10^6 K volumes are less than few percent.

4:30PM VI2.00004 Laboratory study of auroral cyclotron emission processes[1] , KEVIN RONALD, SUPA and Department of Physics, University of Strathclyde — Electrons encounter an increasing magnetic field and increase in pitch angle as they descend towards the auroral ionosphere, according to the conservation of the magnetic moment. This process results in a horseshoe shaped distribution function in electron velocity space which has been observed by satellites [1]. Research has shown this distribution to be unstable to a cyclotron maser instability [2] and the emitted Auroral Kilometric Radiation is observed to be polarised in the extraordinary mode. Experimental results are presented based on an electron beam of energy 75keV having a cyclotron frequency of 4.45GHz, compressed using magnet coils to mimic the naturally occurring phenomenon. The emitted radiation spectrum was observed to be close to the cyclotron frequency. Electron transport measurements confirmed that the horseshoe distribution function was obtained. Measurements of the antenna pattern radiated from the output window demonstrated the radiation to be polarised and propagating perpendicular to the static magnetic field. The radiation generation efficiency was estimated to be 2% in close agreement to the numerical predictions of the 2D PiC code KARAT. The efficiency was also comparable with estimates of the astrophysical phenomenon.

[1] R. J. Strangeway et al, Geophys. Rev. Lett., 25, 1998, pp. 2065-2068
[2] I Vorgul et al, Physics of Plasmas, 12, 2005, pp. 1-8

[1]Thanks to the AKR team and the EPSRC.

Friday, November 16, 2007 8:00AM - 9:00AM –

Session XR1 Review: Instabilities Driven By Energetic Particles in Magnetized Plasmas Rosen Centre Hotel Junior Ballroom

8:00AM XR1.00001 Instabilities Driven by Energetic Particles in Magnetized Plasmas[1] , WILLIAM HEIDBRINK, University of California, Irvine — Wave heating, beam injection, and fusion reactions create super-thermal ion and electron populations in both natural and laboratory plasmas. The free energy of the energetic particles often drive instabilities. In this review talk, the generic features of these instabilities will be discussed using a class of instabilities known as Alfvén eigenmodes, which occur in spectral gaps associated with periodic variations in the index of refraction. In the first observations of these instabilities, intense neutral beam injection into tokamaks drove instabilities in the spectral gap caused by toroidicity. Later observations worldwide showed the universality of this phenomenon with a wide variety of energetic populations driving instabilities in numerous spectral gaps in stellarators, pinches, and spherical and conventional tokamaks. The extraction of energy from the energetic particles necessarily alters their constants of motion, leading to a degradation in confinement. Both convective and diffusive transport are observed and, in extreme circumstances, the vessel walls are damaged. Recent diagnostic advances show that the measured mode structure is often in excellent agreement with theoretical predictions; on the other hand, the observed fast-ion transport is often larger than expected. The nonlinear dynamics is complex. In some circumstances, bursts of wave activity cause fast-particle loss, resulting in relaxation oscillations. In others, structures in phase space associated with a single coherent mode cause frequency sweeping. In still others, multiple unstable modes result in gradual flattening of the fast-particle pressure profile. The many possibilities pose a challenge for ITER, where intense alpha-particle populations are likely to excite Alfvén eigenmodes.

[1]Supported by US DOE under DE-FC02-04ER54698 and SC-G903402.

Friday, November 16, 2007 9:30AM - 12:30PM –

Session YI1 Ripple and Rotation Studies Rosen Centre Hotel Junior Ballroom

9:30AM YI1.00001 Effects of toroidal field ripple on H-modes in JET and implications for ITER operations , GABRIELLA SAIBENE, EFDA SCU - Garching — The effects of toroidal field ripple (dB) on H-mode confinement are not well understood and were not included in the criteria for the design of the ITER toroidal field coil system. ITER has 18 TF coils, and dB at the plasma outer midplane separatrix position is about 1% or, with the present design of correcting ferritic inset (designed to limit first wall loads from fast ion losses), is reduced to about 0.5% at full field. Experiments were carried out in JET to study the effect of toroidal field ripple dB on ELMy H-modes confinement and pedestal parameters, as well as on ELM type and size. In the experiment, dB at the separatrix was increased to 0.3%, 0.5%, 0.75% and 1% in separate plasma discharges, at approximately constant absorbed power. The main effect of increasing dB is a loss of plasma density (approx 30% to 40%), across the whole plasma profile, observed even at the minimum dB. The H-mode enhancement factor is reduced by up to approximately 20% at 1% ripple compared to reference (dB=0.08%). VTOR decreases by a factor of 4 in the pedestal region when dBgoes from 0.08% to 0.5% At higher dB, VTOR at the plasma edge goes to zero and eventually becomes negative (dB =1%). The H-mode density can be increased by external gas puff and the response of the density to external fuelling is similar for plasmas with and without ripple. Ripple also affects Type I ELM behavior. For plasmas without external gas fuelling, the ELM energy loss is smaller by a factor of 2 with 1% ripple compared to the reference case, due to a reduction of the prompt temperature drop at the ELM. The confinement degradation and loss of density may have worrying implications for the performance of the ITER baseline scenario. The extrapolation of JET results to ITER and possible design solutions for further reduction of dB in ITER will be discussed.

10:00AM YI1.00002 Plasma Rotation Research for Advanced Tokamak Plasma Control in JT-60U , YUTAKA KAMADA, Japan Atomic Energy Agency — The fusion research has to establish an efficient control of the self-regulating plasmas for achieving a high integrated performance. Toward this goal, the mechanisms determining the plasma rotation profile and effects of the rotation on transport and stability are the central issues. Reduction of the toroidal field ripple by installing ferritic steel tiles in JT-60U reduced the fast ion losses and resultant counter plasma rotation drive. By combining this newly achieved freedom of rotation with co-, counter- and perpendicular NBs, JT-60U has been promoting an integrated research project focusing on the plasma rotation covering the research areas of transport, stability, pedestal, and steady state operation. With a new perturbed transport analysis, we successfully separated the diffusive and the non-diffusive terms of the momentum transport in L and H-mode plasmas, clarified their dependences, reproduced the toroidal rotation profile utilizing these evaluated transport coefficients and external torque input, and identified the drive for intrinsic rotation which is determined by the pressure gradient locally. In the type-I ELM regime, we found that the shift of the rotation into the co-direction reduces the inter-ELM transport, enhances the pedestal width and height. The grassy ELM frequency increases almost linearly with increasing counter rotation. Even at zero-rotation, a high ELM frequency with sufficiently small ELM energy loss is obtained. This result encourages applicability of the grassy ELM to ITER. As for the high-beta stability, the critical rotation speed for the resistive wall mode stability was found to be 0.3% of the Alfven speed almost up to the ideal-wall limit. Rreversed shear plasmas with bootstrap fraction $\sim$70% was sustained for 8 s, where the beta-collapse was avoided through reduction of the pressure gradient at ITB by the rotation control.

10:30AM YI1.00003 Spontaneous Plasma Rotation Scaling in the TCV Tokamak , BASIL DUVAL, Centre de Recherches en Physique des Plasmas — Predicting intrinsic plasma rotation that helps stabilize various plasma instabilities that can adversely affect the plasma performance is important for prospective fusion grade devices. ITER-like scenarios have been extrapolated from measured experimental plasma rotation data but little is understood about the underlying mechanisms governing either the generation or dissipation of momentum in a Tokamak plasma. On ITER, rotation is expected to be dominated by intrinsic plasma processes whereas most experimental observations use strong momentum injection sources such as heating Neutral Beams. With a Diagnostic Neutral Beam, driving negligible toroidal velocity, CXRS in TCV provides a high quality direct measurement of the intrinsic plasma toroidal and poloidal rotation profiles for Ohmic and EC-heated plasmas in diverted and limited configurations for a wide range of plasma shaping. The plasma behavior can be separated by the core and edge regions. For limited configurations, core counter-current toroidal rotation scales inversely with plasma current (Scarabosio PPCF 2006) and exhibits a reproducible direction inversion with a <10% rise in plasma density (Bortolon PRL 2006). In diverted configurations, a co-current toroidal velocity reverses direction with a <10% rise in plasma density. Edge toroidal rotation is strongly frictional for limited configurations whereas an edge velocity scaling with core density is observed for diverted configurations. Core toroidal momentum is strongly distributed by sawteeth but the rotation torque evolves and inverts separately from the edge. The behavior of the rotation and deduced radial electric field profiles are shown as a function of plasma shape and compared to changes in other plasma parameters.

11:00AM YI1.00004 Dependence of Edge Turbulence Dynamics and the L-H Power Threshold on Toroidal Rotation[1] , G.R. MCKEE, University of Wisconsin-Madison — The injected power required to induce a transition from L-mode to H-mode plasmas is found to depend strongly on the injected neutral beam torque and consequent plasma toroidal rotation. Edge turbulence and flows, measured near the outboard midplane of the plasma ($0.85 < r/a < 1.0$) on DIII-D with the high-sensitivity 2D beam emission spectroscopy (BES) system, likewise vary with rotation and suggest a causative connection. The L-H power threshold in plasmas with the ion ∇B drift away from the X-point decreases from 4-6 MW with co-current beam injection, to 2-3 MW near zero net injected torque, and to <2 MW with counter injection. Plasmas with the ion ∇B drift towards the X-point exhibit a qualitatively similar though less pronounced power threshold dependence on rotation. 2D edge turbulence measurements with BES show an increasing poloidal flow shear as the L-H transition is approached in all conditions. As toroidal rotation is varied from co-current to balanced in L-mode plasmas, the edge turbulence changes from a uni-modal character to a bi-modal structure, with the appearance of a low-frequency (f=10-50 kHz) mode propagating in the electron diamagnetic direction, similar to what is observed as the ion ∇B drift is directed towards the X-point in co-rotating plasmas. At low rotation, the poloidal turbulence flow near the edge reverses prior to the L-H transition, generating a significant poloidal flow shear that exceeds the measured turbulence decorrelation rate. This increased poloidal turbulence velocity shear may facilitate the L-H transition. No such reversal is observed in high rotation plasmas. This reduced power threshold at lower toroidal rotation may benefit inherently low-rotation plasmas such as ITER.

[1]Supported by US DOE under DE-FG02-89E R53296 and DE-FC02-04ER54698.

11:30AM YI1.00005 Measurements and implications of particle and momentum transport from magnetic stochasticity in MST

, WEIXING DING, Department of Physics, University of California, Los Angeles — Magnetic stochasticity associated with radial magnetic field fluctuations (δb_r) is expected to have significant effects on plasma transport. Particle and momentum transport due to stochastic magnetic fields are defined as $\frac{<\delta j_{//,e}\delta b_r>}{eB_0}$ and $\frac{<\delta p_{//,i}\delta b_r>}{B_0}$, respectively, where $\delta j_{//,e}$ and $\delta p_{//,i}$ are parallel electron current density fluctuations and parallel ion pressure fluctuations. A recently developed differential interferometer method is used to measure local density fluctuations, while a fast Faraday rotation diagnostic measures radial magnetic field fluctuations and current density fluctuations. Direct measurements of particle and momentum transport during reconnection events (the crash phase of a sawtooth oscillation) in the MST reversed field pinch show that; (1) the magnetic fluctuation-induced particle flux accounts for the change in the core equilibrium density, and (2) the convective component of the *momentum* transport from stochasticity is of sufficient magnitude to contribute to the known anomalous momentum transport in the plasma core. Furthermore, the difference between magnetic fluctuation-induced electron flux and ion flux, ($\frac{<\delta j_{//}\delta b_r>}{eB_0}$), has been experimentally determined by measuring Maxwell stress directly in the plasma core. It is nonzero (transport is locally nonambipolar) and produces a large radial electric field (and field shear) localized to the reconnection (resonant) surface. This electric field implies the existence of a localized *zonal flow* that reverses direction about a reconnection surface – a new mechanism for zonal flow generation. Author acknowledges contributions from D.L. Brower, B.H. Deng, T.F. Yates, UCLA, and the MST team. Work is supported by DoE and NSF.

12:00PM YI1.00006 Turbulent Equipartition Theory of Toroidal Momentum Pinch[1]

, T.S. HAHM, Plasma Physics Laboratory, Princeton University — The turbulent convective flux (pinch) of the toroidal angular momentum density is derived using the nonlinear toroidal gyrokinetic equation which conserves phase space density and energy[1], and a novel pinch mechanism which originates from the symmetry breaking due to the magnetic field curvature is identified. A net parallel momentum transfer from the waves to the ion guiding centers is possible when the fluctuation intensity varies on the flux surface, resulting in imperfect cancellation of the curvature drift contribution to the parallel acceleration. This pinch velocity of the angular momentum density can also be understood as a manifestation of a tendency to homogenize the profile of "magnetically weighted angular momentum density," $nm_iRU_\parallel/B^2$. This part of the pinch flux is mode-independent (whether it's TEM driven or ITG driven), and radially inward for fluctuations peaked at the low-B-field side, with a pinch velocity typically, $V_{Ang}^{TEP} \sim -2\chi_\phi/R_0$. We compare and contrast the pinch of toroidal angular momentum with the now familiar "turbulent equipartition" (TEP) mechanism for the particle pinch[2] which exhibit some relevance in various L-mode plasmas in tokamaks. In our theoretical model[3], the TEP momentum pinch is shown to arise from the fact that, in a low-β tokamak equilibrium, $B^2\mathbf{u}_E = c\mathbf{B}\times\nabla\delta\phi$ is approximately incompressible, so that the magnetically weighted angular momentum density ($m_inU_\parallel/B^3 \propto m_inU_\parallel R/B^2$) is locally advected by fluctuating $\mathbf{E}\times\mathbf{B}$ velocities, to the lowest order in $O(a/R)$. As a consequence $m_inU_\parallel R/B^2$ is mixed or homogenized, so that $\frac{\partial}{\partial\psi}m_inU_\parallel R/B^2 \rightarrow 0$.

[1] T.S. Hahm, Phys. Fluids **31**, 2670 (1988)
[2] V.V. Yankov, JETP Lett. **60**, 171 (1994); M.B. Isichenko *et al.,* Phys. Rev. Lett. **74**, 4436 (1995); X. Garbet *et al.,* Phys. Plasmas **12**, 082511 (2005).
[3] T.S. Hahm, P.H. Diamond, O. Gurcan, and G. Rewoldt, Phys. Plasmas **14**, 072302 (2007).

[1]In collaboration with P.H. Diamond, O. Gurcan, and G. Rewoldt. Work supported by U.S. Department of Energy.

Friday, November 16, 2007 9:30AM - 12:00PM – Session YI2 HEDP and Plasma Simulations Rosen Centre Hotel Salon 3/4

9:30AM YI2.00001 High-Intensity-Laser–Solid Interactions in the Refluxing Limit

, P.M. NILSON, Laboratory for Laser Energetics, U. of Rochester — Small mass targets are of interest in high-intensity-laser–solid interactions due to their unique fast-electron transport properties.[1,2] Electron refluxing in solid-density matter by the Debye sheath fields that are set up at the target surfaces provide a unique environment for the determination of the conversion efficiency of laser energy into fast electrons.[3] Previous measurements of the absolute K$_\alpha$ yield from copper foils as a function of laser intensity demonstrate excellent agreement with electron refluxing models.[3,4] In particular, fast-electron conversion efficiencies of around 10% to 20% have been inferred by fitting the absolute K$_\alpha$ yields to semi-analytical modeling. It is well known that ionization of the M shell during volumetric heating within such small mass copper targets can cause a deviation in the ratio of the number of emitted K$_\beta$ and K$_\alpha$ photons below the cold material limit.[4] This is a direct consequence of bulk target heating due to fast-electron energy loss. Such a deviation could provide a useful code benchmarking parameter on the energy content of the fast electrons and a consistency check on the laser-electron conversion efficiency. This consistency check, however, has proven elusive experimentally. We demonstrate here for the first time the consistency between the fast-electron conversion efficiencies predicted by these two methods using small mass targets. It is demonstrated that a 3.5× reduction in the ratio of the number of emitted K$_\beta$ and K$_\alpha$photons is achievable below the cold material limit using $20 \times 20 \times 2$ μm copper targets at laser intensities of 2×10^{19} W cm^{-2}. These results provide a comparison in preparation for the higher energy-density environments that will be accessible using the future OMEGA EP Laser Facility.[5] This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreements DE-FC52-92SF19460 and DE-FC02-04ER54789. Contributors: W. Theobald, J. Myatt, M. Storm, O.V. Gotchev, C. Mileham, C. Stoeckl, R. Betti,* D.D. Meyerhofer,* and T.C. Sangster. *Also at the Fusion Science Center for Extreme States of Matter and Fast Ignition.

[1] S. P. Hatchett *et al.*, Phys. Plasmas **7**, 2076 (2000).
[2] R. A. Snavely *et al.*, Phys. Rev. Lett. **85**, 2945 (2000).
[3] W. Theobald *et al.*, Phys. Plasmas **13**, 043102 (2006).
[4] J. Myatt *et al.*, Phys. Plasmas **14**, 056301 (2007).
[5] C. Stoeckl *et al.*, Fusion Sci. Technol. **49**, 367 (2006)

10:00AM YI2.00002 Radiation Transport through Inhomogeneous Materials[1]

, PAUL KEITER, Los Alamos National Laboratory — Calculations of radiation transport in heated materials are greatly complicated by the presence of regions in which two or more materials are inhomogeneously mixed. This phenomenon is important in many systems, including inertial confinement fusion (ICF), where mixing can occur from instability growth and in astrophysical systems where density clumps can be found in star-forming regions and molecular clouds. We describe laboratory experiments designed to test the modeling of radiation transport through inhomogeneous plasmas. A laser-heated hohlraum is used as a thermal source to drive radiation through polymer foam containing randomly-distributed gold particles. We present experimental measurements of radiation transport in foams with gold particle sizes ranging from 5-9 micron to sub-micron diameters as well as the homogeneous foam case. We also compare simulation results of the radiation transport to the experiment. This was performed by the Los Alamos National Laboratory under the auspices of the United States Department of Energy under contract no. W-7405-ENG-36.

[1]Coauthors: Mark Gunderson (LANL) John Foster, Paula Rosen, Mark Taylor and Andrew Comley (AWE)

10:30AM YI2.00003 Charged Particle Stopping Power Effects on Ignition: An Exact Calculation

, ROBERT SINGLETON JR., Los Alamos National Laboratory — Using a new technique designed to capture both long and short distance physics in a completely finite manner, I will calculate the charged particle stopping power exactly to leading and next-to-leading order in the plasma number density, including an exact treatment of two-body quantum scattering. I should emphasize that this is not a model but a systematic calculation that provides an estimate of its own error and its domain of applicability. This calculation is extremely accurate in the plasma regime realized during ICF ignition, and the 3.5 MeV alpha particle range tends to be 30 to 40% longer than most models in the literature have predicted. This increases the rho-R required for ignition.

11:00AM YI2.00004 Toward Petaflop First Principles Kinetic Plasma Simulation[1]

, KEVIN BOWERS[2], Plasma Theory and Applications (X-1-PTA), Los Alamos National Lab, MS B259, PO Box 1663, Los Alamos, NM 87545 — Due to physical limitations (such as the speed of light), moving data between and even within modern microprocessors is more time consuming than performing computations. As a result, individual processor core performance is stagnant, multicore processors are ubiquitous and traditional programming styles are unable to exploit the potential of modern computers fully. This talk will discuss the architecture and implementation of the 3d electromagnetic relativistic particle-in-cell code VPIC for LANL's Roadrunner supercomputer. Roadrunner is expected to have 13,000 IBM Cell microprocessors (each Cell contains a dual threaded Power core and 8 specialized vector cores) and be capable of over a petaflop (10^{15} floating point operations per second). VPIC minimizes data movement and allows vector extensions of modern processors to be utilized portably. This made it possible to port VPIC quickly while achieving unprecedented performance. The initial port performed 0.13 billion particles pushed and accumulated per second per Cell—equivalent to 1.0 billion per second per 8 Cell node or sustaining Roadrunner at 0.4 petaflop. Higher performance is likely as the port is refined. Regardless, already demonstrated performance will enable previously intractable simulations in numerous areas of plasma physics, including magnetic reconnection and laser plasma interactions.

[1] LA-UR-07-4830. Thanks to Brian Albright, Ben Bergen, Lin Yin and Thomas Kwan. This work was performed under the auspices of the US Dept of Energy by the Los Alamos National Security LLC Los Alamos National Laboratory under contract DE-AC52-06NA25396.

[2]Guest Scientist. Presently at D E Shaw Research LLC, 120 W 45th St, New York, NY 10036.

11:30AM YI2.00005 Noninvariance of Space- and Time-Scale Ranges under a Lorentz Transformation and the Implications for the Study of Relativistic Interactions[1]

, JEAN-LUC VAY, Lawrence Berkeley National Laboratory — We present an analysis which shows that the ranges of space and time scales spanned by a system are not invariant under Lorentz transformation [1]. This implies the existence of a frame of reference which minimizes an aggregate measure of the range of space and time scales. Such a frame is derived, for example, for the following cases: free electron laser, laser-plasma accelerator, and particle beams interacting with electron clouds. The implications for experimental, theoretical, and numerical studies are discussed. The most immediate relevance is the reduction by orders of magnitude in computer simulation run times for such systems. A speed-up of 1000 was obtained on a proof-of-principle Particle-In-Cell simulation of a relativistic proton beam experiencing a hose-like instability as propagating through a high density of electrons in a uniform focusing channel. We are in the process of upgrading our simulation tools to be in a position to perform simulations in the optimal frame, and apply them to actual situation for the identified areas of applications. We will present results, as available. [1] Phys. Rev. Lett. 98, 130405 (2007)

[1]This work was supported under the auspices of the U.S DOE by Univ. of Calif., LBNL under contract DE-AC02-05CH11231, and by the U.S.-LHC Accelerator Research Program (LARP).

Friday, November 16, 2007 9:30AM - 11:54AM –

Session YO5 Target Fabrication and HEDP Rosen Centre Hotel Salon 11/12

9:30AM YO5.00001 Forming Cryogenic DT Targets for OMEGA

, D.R. HARDING, D.H. EDGELL, L.M. ELASKY, Laboratory for Laser Energetics, U. of Rochester — Experiments at LLE have shown that it is possible to fill thin-walled plastic capsules with a mixture of deuterium–tritium (DT) in 3 days and form a 70 to 95-μm ice layer with an inner surface roughness better than 1-μm rms in an additional day. Of the 33 DT targets that have been processed, the average ice roughness is 1.4$\pm$0.9 μm with a median value of 1.4 μm; eight of the targets had a roughness below 1.0-μm rms. The smoothest ice layer possessed a roughness of 0.5-μm rms, a value where the roughness of the plastic capsule's surface and the sensitivity of the shadowgraphy technique begin to affect the accuracy of the analysis. Repeated melting and relayering of the ice layer in the same capsule yielded sub1μm-rms ice roughness each time. The residual roughness is controlled by the crystal growth process, which requires that an initial single crystal be nucleated within the liquid DT and that its growth rate be finely controlled; if the crystal grows too rapidly, facets and dislocations form within the ice. The effect of these crystalline defects is to distort the shadowgraphic analysis. Other notable observations have been (1) that no ^{3}He bubbles were observed in the DT-ice layers after the layer had aged for 19 days, and (2) that transparent DT-ice layers were formed in foam targets (0.16- and 0.116-g/cm^3 foam density). This work was supported by the U.S. DOE under Cooperative Agreement DE-FC52-92SF19460.

9:42AM YO5.00002 Development of a laser-produced plasma x-ray source for phase-contrast imaging of DT fuel ice layers[1]

, N. IZUMI, Livermore National Laboratory, Livermore CA, 94550, E. DEWALD, B. KOZIOZIEMSKI, J.A. KOCH, Lawrence Livermore National Laboratory — Because beryllium capsules for NIF experiments are not transparent to visible light, optical microscopy is not applicable for metrology of deuterium-tritium (DT) ice layers. X-ray absorption radiography cannot be used either because absorption in DT ice is negligible, so to quantify the quality of the DT ice surface, x-ray phase-contrast imaging is used in order to enhance contrast of surface imperfections. Phase contrast imaging of ice layers typically utilizes micro-focus x-ray tube sources, but available x-ray fluxes are limited, and these sources cannot be used to quantify changes in the ice surface quality over the second timescales appropriate for rapidly-cooled layers. We have therefore explored the use of a laser-produced plasma x-ray source in order to determine if it has sufficient brightness to produce high-quality phase-contrast flash radiographs of DT ice layers. We irradiated Ti, Fe, Cu, and Au targets with 5-ns, 300-J, 527-nm laser light at the Janus laser facility, and measured absolute x-ray conversion efficiency and x-ray spot size. We will discuss this data as well as phase-contrast radiographs we obtained of non-cryogenic shells.

[1]This work was performed under the auspices of the U.S. DOE by the Univ. of California, LLNL under contract No. W-7405-Eng-48.

9:54AM YO5.00003 Target Fabrication in Support of Inertial Confinement Fusion and High Energy Density Physics Experiments[1] , C.A. BACK, A. NIKROO, J.D. KILKENNY, General Atomics, A.V. HAMZA, L.J. ATHERTON, Lawrence Livermore National Laboratory — Target fabrication is increasingly important in experiments for inertial confinement fusion and high energy density physics. As the facilities are nearing completion and programs become more mature, refinements and new target designs remain a path to explore new physics through development of new materials and techniques. To meet the needs of the laboratory and academic communities, the target fabrication groups are working together across the DOE and NNSA complex to make best use of facilities and capabilities at the different sites. The challenge of target fabrication is to place new materials with sub-micron to micron tolerances into mm-sized packages. Targets are often needed in limited quantities, and even for a point design, flexible fabrication support is needed to meet evolving needs, making it difficult to take advantage of economies of scale. Here, we highlight the target ordering process we have implemented to specify, track, and use resources as efficiently as possible.

[1]Supported by General Atomics IR&D funding and W-7405-ENG-48.

10:06AM YO5.00004 Fabrication and Metrology of Ignition Design Graded Copper Doped Beryllium Capsules With Fill Tubes[1] , A. NIKROO, M.S. CONYERS, S.A. EDDINGER, A.C. FORSMAN, H. HUANG, E.H. LUNDGREN, K.A. MORENO, H. XU, K.P. YOUNGBLOOD, Z.A. ZIMMERER, General Atomics, S.D. BHANDARKAR, C.S. ALFORD, S.A. LETTS, J.L. REYNOLDS, LLNL — Graded doped beryllium is currently the baseline ablator in designs for achieving ignition in the National Ignition Facility (NIF). In this paper, we report on the progress towards fabricating and characterizing such beryllium capsules for NIF ignition designs. We have eliminated the unanticipated gas leakage observed in graded copper doped beryllium capsules made by sputter coating by ion-assisted deposition. Polishing and mandrel selection render shells that meet the surface roughness. Precision radiography measures azimuthal x-ray optical depth of the shell to 10^{-4}. Laser drilling produces 5 μm holes in full thickness shells. Progress towards drilling a counter bore and 10 μm fill tube attachment to ignition design will be discussed. Improvements in metrology of Cu dopant and contaminant profile using quantitative contact and electron probe techniques will be also presented.

[1]Supported by US DOE under DE-AC52-06NA27279 and W-7405-ENG-48.

10:18AM YO5.00005 Fabrication of Embedded Spheres in Resorcinol Formaldehyde Aerogel for Astrophysical Jet Experiments on OMEGA[1] , R.R. PAGUIO, J.F. HUND, B.E. BLUE, D.G. SCHROEN, K.M. SAITO, C.A. FREDERICK, R.J. STRAUSER, General Atomics, K. QUAN, University California-San Diego — Embedded sapphire spheres in a cylindrical resorcinol formaldehyde aerogel targets are required for astrophysical jet studies on OMEGA. Previous work done on fabricating such a target used a 100 μm thick stalk in order to place the ball in the required position. Recent experiments required the stalk to be 1 μm or less, and changed the aerogel density from 100 mg/cc to 300 mg/cc. Targets were successfully fabricated without a supporting stalk by modifying parameters such as gelation time of the aerogel precursor solution, and use of a vacuum holder for the sphere placement. Fabrication of this target was also developed using a spider silk support approximately 100 times thinner than the earlier work on similar targets. Characterization of the ball placement and aerogel was done by radiography. These measurements showed that the ball was accurately placed and the aerogel matrix was not significantly altered.

[1]Supported by the US DOE under DE-AC52-06NA27279.

10:30AM YO5.00006 Fabrication of Astrophysically Relevant Targets for Use on Inertial Confinement Fusion Machines[1] , B.E. BLUE, C.A. BACK, J.F. HUND, R. PAGUIO, D.G. SCHROEN, GA, J.M. FOSTER, P.A. ROSEN, R.J.R. WILLIAMS, AWE, B.H. WILDE, R.F. COKER, LANL, R. WALLACE, J.F. HANSEN, LLNL, R.M. STAMM, Schafer Corp, J. PALMER, R. CARVER, P. HARTIGAN, Rice U. — A series of experiments has been conducted on the Omega laser at the University of Rochester that scale to astrophysical jets. We have fielded experiments to study the hydrodynamic evolutions of high-Mach-number jets, jets deflecting from a high-density sphere that simulate astrophysical jets interacting with stellar clouds at different impact parameters, jets evolving into foams of varying cell size to understand the effect of medium inhomogeneity, and shocks impacting a dense sphere to simulate shocks interacting with gas clouds. This talk will present the target fabrication challenges related to these experiments. Such challenges include foam production, precisely embedding objects in foams, assembling the multiple components with tight tolerances, and the extensive metrology and characterization that is needed to accurately model, and derive results from, these experiments.

[1]Supported by the US DOE DE-AC52-06NA27279 and W-7405-ENG-48.

10:42AM YO5.00007 Fabrication of Planar Foam Targets for Rayleigh-Taylor Instability Experiments[1] , C.A. FREDERICK, R.R. PAGUIO, J.F. HUND, General Atomics — Cryogenic direct-drive inertial confinement fusion (ICF) experiments at the Omega Laser Facility require 180 mg/cc resorcinol formaldehyde (RF) foam shells overcoated with a full density layer of CH. Surface perturbations on the overcoated shells can amplify Rayleigh-Taylor instabilities during target implosion. To study Rayleigh-Taylor instability, planar foam targets with a full density CH coating were fabricated. In an effort to also better understand the different modes of instability single sine waves with varying wavelengths and amplitudes were laser machined into the full density layer of CH. Fabrication of the planar foam pieces, application of the full density CH layer, and laser patterning will be discussed. Characterization of the laser-machined patterns was done using interferometric and radiographic techniques.

[1]Supported by the US DOE under DE-AC52-06NA27279.

10:54AM YO5.00008 Density Uniform and Surface Characterization of Tantalum Oxide Aerogel for Radiation Transport Experiments[1] , J.F. HUND, C.A. FREDERICK, A.P. TIPTON, E.M. GIRALDEZ, J.L. KAAE, C.A. BACK, M.L. HOPPE JR, General Atomics — Tantalum aerogel was fabricated and machined at General Atomics for radiation transport experiments at the OMEGA laser facility. These targets are machined into small disks from 250 or 500 mg/cc tantalum oxide aerogel. During machining, differences in density uniformity and machining characteristics were observed in some of the aerogels. Ultimately, rough surfaces or intrinsic density variations in the sample can lead to areal density non-uniformities that can affect the experiment. Using contact radiography, optical profilometry, and scanning electron microscopy the surface roughness and areal density uniformity were quantified. This information was used to improve the synthesis procedure of the bulk aerogel material to fabricate more uniform aerogel targets and provide input for comparison shot data of experiment vs modeling data.

[1]Supported by General Atomics IR&D funding.

11:06AM YO5.00009 Fundamental Limits on the Maximum Aspect Ratios of Laser Drilled Holes[1] , A.C. FORSMAN, E.H. LUNDGREN, A.M. KOMASHKO, General Atomics — The drilling of <6 μm diameter holes in 170 μm deep shells has been demonstrated using a nanosecond laser system that produces a formatted pulse output where each laser shot consists of a pair of timed nanosecond laser pulses. This work was done to enable gas fills in beryllium capsules for inertial confinement fusion experiments. This is an involved goal in laser process development. The interplay of material characteristics, hydrodynamic flows, and laser-matter interactions have been studied. The drilling process will be described, as well as possible limitations on the maximum ratio of hole depth to hole width that are imposed by the laser matter interactions, the material properties and the laser produced plasmas themselves.

[1]Supported by the US DOE under DE-AC52-06NA27279.

11:18AM YO5.00010 LASNEX Radiation Wave Simulations and Implications for Temperature Measurements , HEIDI TIERNEY, Los Alamos National Laboratory, ROBERT PETERSON, PAUL KEITER, THOMAS TIERNEY, GLENN MAGELSSEN, LANL — LANL is developing a diagnostic platform that will allow temperature measurements of a radiation front as it propagates through a medium. These diagnostic development experiments, called NIF Platform Five, are being performed at University of Rochester's 60-beam OMEGA laser. The OMEGA NIF-5 experiments use a 3/4-scale hohlraum mounted on the P6-P7 axis. Fifteen beams are used to drive the hohlraum to radiation temperatures near 220-240 eV in a 1-ns pulse. A radiation wave flows through a 60-mg/cc CHCl foam, which is mounted in a cylinder on the opposite side of the hohlraum from the 0.8-mm diameter LEH. A backlighter is used to perform measurements of absorption spectroscopy for electron temperature determination, while self emission is the primary process that allows measurement of radiation front position. We present 2-D R-Z LASNEX simulations of data taken at OMEGA using a soft x-ray framing camera in January 2007. The simulated laser drive, target shape, and material composition replicate experimental conditions for individual shots as closely as possible. Post processing tools for radiation transport and filtering have been used for final comparison with the soft x-ray camera measurements. Data comparison to simulation and implications for temperature measurements will be discussed.

11:30AM YO5.00011 Measurements of X-ray energy flow through evolving density gradients to validate the modeling of stellar atmospheres , P. GRAHAM, J. FOSTER, A. MOORE, M. TAYLOR, AWE Aldermaston, UK, S. MACLAREN, P. YOUNG, G. GLENDINNING, A. REIGHARD, C. SORCE, LLNL Livermore, USA, C. BACK, J. HUND, B. BLUE, GA, San Diego, USA — Density perturbations, such as N-waves, in stellar atmospheres are coupled to the X-ray radiation field and so their evolution is challenging to simulate [1]. To assess current modeling capabilities an analogous problem was generated on the LLE OMEGA laser using a hohlraum to drive X-rays through tantalum aerogel with an initial seed perturbation. X-rays diffuse preferentially through the lower density material and the flow changes over time as the heated mass evolves. The energy flow was diagnosed using two methods, direct flux and hohlraum calorimetry, which are compared to assess the best technique. In both cases multiple flux diagnostics on different lines of sight were used, including photodiode and photoconductive detectors, to crosscheck results. In addition, 2D framing images of X-ray emission were taken to correlate with the flux measurements. The suite of data will be presented and compared against modeling. [1] Mihalas & Mihalas, 'Foundations of Radiation Hydrodynamics', Dover (1999).

11:42AM YO5.00012 On-axis Hohlraum Radiography associated with N-Waves in Stellar Atmospheres. , A.S. MOORE, J. FOSTER, P. GRAHAM, M. TAYLOR, AWE Aldermaston, UK, S. MACLAREN, P. YOUNG, G. GLENDINNING, A. REIGHARD, C. SORCE, LLNL Livermore, USA, C. BACK, J. HUND, B. BLUE, GA, San Diego, USA — The propagation of weak shocks in a stellar atmosphere, in conjunction with the high x-ray flux cannot be well-described using weak-shock theory. Experiments performed at the LLE OMEGA laser attempt to study shock dynamics similar radiation conditions. Point-projection radiography was performed along the axis of a 160eV hohlraum, illuminating the structures formed by the ablation of a 0.2mm annular slot in a solid Ta disc. Diagnosed whilst laser-driven, the platform also enables quantitative measurements of x-ray flow through high-Z foam slot. Backlit images of the radiatively-driven slot show complex 'bubble-like' features at the intersection of ablation fronts. Despite the 3D aspects of the experiment, 2D simulations, using the radiation-hydrodynamics code are an excellent qualitative match to the data, demonstrating that structures result from a high pressure spike that forms from the colliding ablation fronts driving a blast wave-like expansion into the dense stagnation region.

Friday, November 16, 2007 9:30AM - 12:18PM –
Session YO6 Hohlraum Physics II Rosen Centre Hotel Salon 5/6

9:30AM YO6.00001 Usefulness of a Rugby-shaped hohlraum in a Laser MégaJoule (LMJ) 40-quad configuration , G. MALINIE, M. VANDENBOOMGAERDE, J. BASTIAN, D. GALMICHE, S. LAFFITE, S. LIBERATORE, CEA, BP 12, 91680 Bruyères le Châtel, France — The LMJ setup will consist of 60 quads in a 3-cone configuration, at angles 33.2°, 49° and 59.5°. First ignition attempts in indirect drive are planned to be made on the way to the completion of the full facility, with only 40 quads in a 2-cone configuration, at angles 33.2° and 49°. By analytic considerations, we show that in a 40-quad configuration, the angular location of the hohlraum outer irradiating ring, as seen from the capsule, must be closer to the laser entrance hole than with the full LMJ. The use of a Rugby-shaped hohlraum instead of a cylinder therefore allows to keep a correct symmetry while reducing the wall surface, which improves the global energetic efficiency of the target. Simplified 2D numerical simulations of Rugby hohlraums are presented, achieving a yield of about 30 MJ with our 1.215 mm-radius, CH-uniform-ablator capsule. These results suggests this kind of hohlraum might be an interesting candidate for 40-quad ignition experiments. Work on optimizing the present design and refining the numerical simulations is currently pursued.

9:42AM YO6.00002 Experimental comparison of symmetry in rugby and cylindrical holhraums , FRANCK PHILIPPE, CEA/DIF, BP 12, 91680 Bruyeres-le-chatel, France, VERONIQUE TASSIN, STEPHANE LAFFITE, MARIE-CHRISTINE MONTEIL, JOSIANE BASTIAN, LAURENCE LOURS, BRUNO VILLETTE, PHILIPPE STEMMLER, SOPHIE BEDNARCZYK, BENOIT RENEAUME, PASCALE DI NICOLA, VINCENT RAFFIN — Recently, holhraum shape optimization has been investigated as a practical way to achieve ignition at lower energy [1][2]. Rugby shaped holhraums theoretically allow better energetic coupling and symmetry control than classical cylinders. As a first step toward an experimental validation of this design, this talk presents the results of experiments on the OMEGA laser facility dedicated to the comparison of symmetry in cylindrical and rugby holhraums. Foamball radiographs and Symcaps emission contours for both type of holhraums are compared to numerical simulation results.

[1] M. Vandenboomgaerde *et al.*, accepted by Phys. Rev. Lett.
[2] P. Amendt *et al.*, Phys. Plasmas **14**, 056312 (2007)

9:54AM YO6.00003 Long pulse gas-filled halfraums on OMEGA for high growth-factor ablative Rayleigh-Taylor experiments , ALEXIS CASNER, G. HUSER, B. VILLETTE, M. VANDENBOOMGAERDE, D. GALMICHE, S. LIBERATORE, F. PHILIPPE, L. MASSE, CEA-DAM ILE DE FRANCE, BP 12, BRUYERES LE CHATEL, F-91190, FRANCE TEAM — Mitigation of Rayleigh-Taylor instabilities growth is crucial to enhance the performance of LMJ and NIF ignition targets. We recently develop on OMEGA a long-pulse platform in order to experimentally prove two mechanisms invoked for RTI stabilization, i.e the graded-doped ablator [1] and the new laminated ablator concept [2]. We used gas-filled halfraums (1 atm neopentane) and stack up to 20 drive beams along 3 cones to create a 7 ns long radiation drive. The new E-IDI-300 phase plates were associated with 1D SSD and halfraum energetics was validated along P5/P8 axis for backscattering measurements along 2 cones. We will also present the first face-on radiographies for modulated CH(Ge) samples and compare them with FCI2 hydrocodes simulations. Foil thickness optimization based on these simulations allows us to anticipate growth factors up to 500 in optical depth and the experimental emulator designs for [1,2] will be presented.
[1] S.W. Haan *et al.*, Phys. Plasmas **12**, 056316 (2005).
[2] L. Masse., Phys. Rev. Lett. 98, 245001 (2007). DPP07 invited talk.

10:06AM YO6.00004 Tradeoffs of efficiency and symmetry control for z-pinch driven ICF hohlraums[1] , R.A. VESEY, M.C. HERRMANN, S.A. SLUTZ, M.E. CUNEO, J.L. PORTER, Sandia National Laboratories — Time-dependent symmetry control for a double z-pinch driven hohlraum using only structures within the hohlraum has allowed the symmetric implosion and ignition of a 500 MJ inertial fusion capsule in detailed two-dimensional simulations [1]. The secondary hohlraum surrounding the capsule has a case-to-capsule radius ratio of 3.8, which provides geometric averaging of modes P_6 and higher, while mode-selective burnthrough shields provide time-dependent control of modes P_2 and P_4. The clearest path to improving the hohlraum efficiency and increasing the system energy gain is to decrease the amount of x-ray energy deposited in the hohlraums that surround the imploding z-pinches, which may be achieved by reducing the wall area. This computational study quantifies the tradeoffs between system efficiency and symmetry control for the 500 MJ capsule in reduced case-to-capsule ratio hohlraums and in single-ended (1-pinch) and double-ended (2-pinch) hohlraums. [1] R. A. Vesey *et al.*, Phys. Plasmas **14**, 056302 (2007).

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

10:18AM YO6.00005 Time-dependent radiation drive asymmetry compensation of inertial fusion capsules by ablator doping , STEPHEN SLUTZ, ROGER VESEY, MARK HERRMANN, Sandia National Labs — Ablator doping, the process of adding small amounts of specific materials to tailor the opacity of the ablator, is shown to be an effective means of compensating for radiation drive asymmetries. As an example, an inertial fusion capsule with a beryllium ablator variably doped with gold has been designed to compensate for a P_2 radiation asymmetry of 20% and still produce nominal fusion yield. In contrast, the same capsule without variable doping, fails when the P_2 asymmetry exceeds 2%. The technique can compensate time-dependent asymmetries by varying the doping as a function of depth within the ablator. We also show that doping can compensate for high levels of other low order modes, e.g. P_1, P_4, and P_6radiation asymmetries.

10:30AM YO6.00006 Laser performance on the National Ignition Facility[1] , MICHAEL SHAW, C.A. HAYNAM, W.H. WILLIAMS, C.C. WIDMAYER, M.A. HENESIAN, R.A. SACKS, S.N. DIXIT, P.J. WEGNER, S.T. YANG, B.M. VAN WONTERGHEM, Lawrence Livermore National Laboratory — The Laser Performance Operations Model (LPOM) [1] was developed to automatically set up, and diagnose the performance of the National Ignition Facility (NIF). LPOM uses the detailed physics model, Virtual Beamline (VBL) [2], for its energetics predictions. We will present comparisons of LPOM predictions with results of a series of laser shots where one beam in a quad was diagnosed at both 1w and 3w with the Precision Diagnostic Station (PDS). The comparisons will include pulse shaping, energetics, frequency conversion, shape timing adjustments, and spatial fluence in both the near and far field. An analysis of the shot-to-shot power repeatability for ignition pulses will also be presented.
[1] M. Shaw, et al, Optical Engineering, 43, 2885-2895 (2004).
[2] C. Haynam, et al, Applied Optics Journal Vol. 46, No. 16/1 June 2007.

[1]Work performed under the auspices of the U.S. DOE by the UC Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48. UCRL-ABS-232888.

10:42AM YO6.00007 NIF power balance performance modeling and testing[1] , D.H. KALANTAR, S.N. DIXIT, C.A. HAYNAM, N.C. MEHTA, M.J. SHAW, C.C. WIDMAYER, W.H. WILLIAMS, Lawrence Livermore National Laboratory, NIF PDS TEAM — A model for predicting power balance performance on the National Ignition Facility (NIF) has been developed. The Power Balance Model (PBM) uses Laser Performance Operations Model (LPOM) runs with statistical variations in laser performance beam-to-beam and quad-to-quad. We have used this model to predict power balance performance for full NIF ignition shots. These predictions will be presented and compared with results from a series of single quad laser shots where one beam was diagnosed at 3w with the Precision Diagnostic Station (PDS) [1]. The shot-to-shot power repeatability from these PDS tests is consistent with the predicted power balance performance, and with the performance requirements for the ignition campaigns.
[1] C. Haynam, et al, International Conference on Inertial Fusion Sciences and Applications, 2007.

[1]This work was conducted by under the auspices of the US DOE by the UC Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

10:54AM YO6.00008 Calculating response of NIF ignition capsules to random 3D errors[1] , O.S. JONES, J.L. MILOVICH, D.A. CALLAHAN, S.W. HAAN, C.C. WIDMAYER, LLNL — To estimate the probability of ignition for a given ICF capsule design, an error budget has been developed in which an allowable range of values for each important parameter is defined. We generally categorize the deviations of each parameter from its ideal value as 1D (affecting the implosion velocity and fuel entropy) or 3D (affecting the amount of distortion of the imploded core at time of maximum compression). In this work we focus on estimating the effect of various 3D errors. To do this we carried out numerous 3D calculations of ignition hohlraums and capsules with imposed errors in laser beam pointing, laser power, capsule centering, etc. The calculations were done using the Hydra radiation hydrodynamics code. The large size and number of required simulations presented new challenges for completing the studies in a reasonable amount of time. We will quantify the effect of each type of 3D random error and assess its impact on the overall error budget rollup.

[1]Work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

11:06AM YO6.00009 Measurements of the non-uniformities seeded by NIF ignition capsule ablator materials[1]

P.M. CELLIERS, D.J. ERSKINE, S.T. PRISBREY, D.G. BRAUN, J.B. RICHARDS, C.M. SORCE, G.W. COLLINS, R.J. WALLACE, O.L. LANDEN, LLNL, A. NIKROO, General Atomics — Current NIF ignition target designs contain the DT fuel inside spherical capsules made of either Cu-doped Be or high density C (HDC). Both candidate materials are polycrystalline, and are expected to respond anisotropically to the initial compression wave of the NIF compression sequence. Estimates of the amplitudes of the non-uniformities seeded by each type of ablator suggest that these capsules should remain stable during the subsequent implosion; however, experiments are needed to verify these estimates. We describe experiments designed to measure shock front perturbations induced by the microscopic polycrystalline non-uniformities of these two ablator materials. The measurement method employs a time-resolved two-dimensional imaging VISAR illuminated by a 2 ps laser pulse, which captures spatial variations in the velocity across the shock front transmitted through the ablator. The measurement is carried out over an 800 μm field of view with relative velocity sensitivity ΔV/V $\sim 10^{-4}$, and over perturbation wavelengths in the range from 3-4 μm to 50 μm.

[1]This work was performed under the auspices of the U.S. Department of Energy by LLNL under contract number W-7405-ENG-48.

11:18AM YO6.00010 Overview and Recent Results from the HyperV Plasma Gun[1]

F. DOUGLAS WITHERSPOON, ANDREW CASE, SARAH MESSER, RICHARD BOMGARDNER, MICHAEL PHILLIPS, DAVID VAN DOREN, HyperV Technologies Corp., RAYMOND ELTON, ILKER UZUN-KAYMAK, University of Maryland — We present an overview of research at HyperV to develop high velocity dense plasma jets for application to fusion and HEDP. The approach uses symmetrical pulsed injection of high density plasma into a coaxial EM accelerator having a cross-section tailored to prevent formation of the blow-by instability. Two development paths are followed to accomplish this injection step: we compare large arrays of capillary discharges to sparkgaps arranged in a toroidal configuration. Experiments on three test fixtures are described: a 2pi configuration with 64 capillary injectors, a 32 injector prototype gun designed to drive rotation in the Maryland MCX experiment, and a second gun using 112 sparkgap electrodes for injection. Data is presented from visible light spectroscopy, fast optical imaging, Rogowski coils, pressure probes, Bdot probes, photodiodes, and a laser interferometer. Ballistic pendulum tests indicate plasma jets with mass 160 micrograms at 70 km/s have been achieved with plasma density above 10^{15} cm^{-3}.

[1]Work supported by the U.S. DOE Office of Fusion Energy Sciences.

11:30AM YO6.00011 Numerical Simulations of Hypervelocity Plasma Jets[1]

M.W. PHILLIPS, F.D. WITHERSPOON, A. CASE, S.J. MESSER, HyperV Technologies Corp., T.P. HUGHES, D.R. WELCH, Voss Scientific, LLC, I.N. BOGATU, S.R. GALKIN, J.S. KIM, FAR-TECH, Inc. — Numerical simulations with comparisons to experiments of hypervelocity plasma jets in development at HyperV Technologies Corp. are presented. The focus will be on the new plasma jet designed to drive rotation in the University of Maryland MCX experiment. Performance of coaxial plasma jets is typically limited by the blow-by instability. Extensive numerical modeling with the Mach 2 code was used in the optimization of the electrode shapes in order to reduce tendencies to blow-by, resulting in a tapered design. To achieve maximum performance each stage of the pulse discharge, including armature formation, acceleration and detachment from the inner electrode, and transport of the plasma blob must be optimized. Experiments have so far demonstrated that plasma blobs of 160 μgrams can be accelerated to 70 km/sec consistent with simulations. Results will also be presented of simulations using the LSP PIC code to study the microphysics of plasma acceleration in more detail.

[1]Work supported by the U.S. Dept. of Energy Office of Fusion Energy Sciences.

11:42AM YO6.00012 Hyper-Velocity C60-Fullerene Plasma Jets for Disruption Mitigation and HEDP[1]

I.N. BOGATU, S.A. GALKIN, J.S. KIM, FAR-TECH, Inc. — ITER needs a reliable disruption mitigation technique with real-time capability. The basic approach is to convert the plasma energy density ($\sim$1 GJ in 840 m^3) into radiation power within 1 ms and increase the electron density by two orders of magnitude all over the plasma cross section to suppress the runaway electrons avalanche. Impurity injection is the principle solution, but once the impurity atoms are ionized in the thin outer layer of tokamak plasma they can no longer penetrate the confining magnetic field unless they have high velocity. We present the concept of producing and using hyper-velocity high-density C60-fullerene plasma jets to penetrate into the core tokamak plasma and deliver the necessary mass. We show that plasma slug model indicates that, by using a capacitive driver of 3 MJ, a C60-fullerene jet of 2.5 g can reach 30 km/s and penetrate half minor radius of ITER plasma. The heavy ion component leads to a high Mach number of the high density (10^{17} cm^{-3}) plasma jet making it an attractive candidate for HEDP studies.

[1]Work supported by the US DOE SBIR program and the US DOE Office of Fusion Energy Sciences.

11:54AM YO6.00013 Inclusion of radiation transport and EOS ionization tables in Hybrid-PIC simulations of plasma jets[1]

PETER HAKEL, UNR, BOB CLARK, TOM HUGHES, CHRIS MOSTROM, Voss, IGOR GOLOVKIN, PAMELA WOODRUFF, JOSEPH J. MACFARLANE, Prism — We report on the progress in plasma simulations using the hybrid particle-in-cell (PIC) code LSP. Recently added modeling capabilities include the effects of ionization and radiation. Transport of radiation is treated in two dimensions using the multigroup diffusion approximation. In addition to free-free opacities, we account for the atomic bound states (i.e., line and bound-free radiation) and plasma self-emission and absorption in modeling of the plasma optical properties. The energy in the radiation field is coupled to the plasma through the absoprtion and emission terms in the plasma energy equation. We use the PROPACEOS equation-of-state (EOS) tables that take into account ionization and other non-ideal effects for the given chemical composition. Gray and multigroup radiation fluxes escaping the plasma are extracted and visualized for diagnostic and engineering purposes. We applied the recently enhanced LSP code to modeling of the plasma jet accelerator experiments at HyperV.

[1]This work is supported by the U.S. Department of Energy Office of Fusion Energy Sciences.

12:06PM YO6.00014 Hybrid PIC Simulations of Particle Dynamics in Coaxial Plasma Jet Accelerators[1]

CARSTEN THOMA, THOMAS HUGHES, DALE WELCH, Voss Scientific, PETER HAKEL, University of Nevada Reno — We describe the results of 1D and 2D simulations of plasma jet accelerators using the particle-in-cell (PIC) code Lsp. Previous studies of 1D cartesian simulations have shown that ion particle dynamics at the plasma-vacuum interface depend critically on the local Hall parameter, which is strongly dependent on electron temperature. In a coaxial accelerator with finite transverse dimensions, large transverse ion motions, predicted at moderate Hall parameters in 1D, can lead to ion loss to the walls. The results of 2D $r-z$ jet simulations are described and compared with the 1D cartesian results. The effects of particle loss and ablation at the wall are considered, as are electron heating mechanisms at the plasma-vacuum interface, including radiation losses. We will apply the results to the plasma jet experiments underway at HyperV Technologies Corp.

[1]This work is supported by the U.S. Department of Energy Office of Fusion Energy Sciences.

9:30AM - 9:30AM –
Session YP8 Poster Session IX: Supplemental and Postdeadline Rosen Centre Hotel Grand Ballroom, 9:30am - 12:30pm

YP8.00001 SUPPLEMENTAL –

YP8.00002 The basic evolution of the angular momentum density in a field-theoretical model of vorticity transport
, FLORIN SPINEANU, MADALINA OLIMPIA VLAD, NILPRP, SADDRUDIN BENKADDA, Universite de Provence, Marseille, France — The structure of the vortical flow of two-dimensional plasmas and fluids evolves under the constraint imposed by the self-organization of the vorticity field, as shown by the extremum of an action functional obtained from the equivalent point-like vortices models. We formulate a field-theoretical model that provides the explicit form of the Lagrangian density and of the equations of motion for the vorticity. In this model the density of the angular momentum results from the field of vorticity and it is possible to infer nondissipative evolutions of the angular momentum from the trend of generating coherent states of the vorticity. The transport of angular momentum exhibits aspects similar to the so-called non-local transport in plasma and also to resilient radial profiles in stable stationary vortices. This can be a significant contribution to angular momentum transport in 2D plasmas, fluids, accreation discs, etc.

YP8.00003 Possible mechanisms for dust grain acceleration in plasmas[1]
, PADMA KANT SHUKLA, LENNART STENFLO, BENGT ELIASSON, Department of Physics, Umea University, SE-90187 Umea, Sweden — There exists conclusive evedince of charged dust grain acceleration in tokamak edges as well as in cosmic plasmas. Our objective here is to present an evaluative description of dust particle acceleration in magnetized dusty plasmas. Possible acceleration mechanisms involve ion drag force caused by plasma flow as well as strong ambipolar electric fields created by the ponderomotive force of large amplitude waves in magnetolasmas. Spatio-temporal scales over which the dust grain acceleration occurs are discussed.

[1]The work supported by the DFG through SFB591 and by the Swedish Research Council (VR).

YP8.00004 Nonlinear Interactions in Dense Quantum Plasmas
, PADMA SHUKLA, Ruhr Universitat Bochum — The purpose of this talk is to discuss some important collective processes in dense quantum plasmas, which are ubiquitous in micromechanical systems and ultrasmall electronic devices, in nanowires, in biophotonics, in intense laser-solid density plasma interaction experiments, as well as in astrophysical and cosmological environments. Tn dense quantum plasmas, which obey the Fermi-Dirac distributions, there are new pressure laws and new quantum forces. The latter are responsible for novel collective interactions at nanoscales in the Fermi plasma. We shall describe the underlying models for dense quantum plasmas and shall discuss new aspects of the quantum fluid turbulence as well as the formation of nanostructures (quantum electron holes and quantum electron vortices) associated with nonlinear plasmonic oscillations. The results of computer simulations reveal interesting dynamics of quantum electron vortices. Furthermore, the nonlinear interactions between intense photons and plasmons exhibit the trapping of localized photons into quantum electron holes. The relevance of our investigation to laboratory experiments and astrophysical settings is discussed.

YP8.00005 Dynamics of Plasma Motion Near Axis in Wire Array
, I.V. GLAZYRIN, RFNC-VNIITF, EU.V. GRABOVSKY, TRINITI, P.V. SASOROV, ITEP — Many non-linear processes are occurred during wire array compression: non-uniformities generation due to overheating instabilities at the initial stages of wire electric explosion; plasma jets formation from separate wire by joint field of wire array. A lot of papers are devoted to these questions. During following stages subshell structures can be formed, which are the result of MHD instabilities development. All described problems are analyzed by 2D and 3D MHD codes. Differences of instabilities development in 3D case and results of axisymmetric simulation are analyzed. This work was supported partially by SNL contract No 380316.

YP8.00006 Vorticity Stabilization of Magnetized Plasma in an Alfven Black Hole.
, FRIEDWARDT WINTERBERG, University of Nevada, Reno — As in an acoustic black hole where the fluid is moving faster than the speed of sound and where the sound waves are swept along, in an Alfven black hole where the plasma is moving faster than the Alfven velocity, the Alfven waves are swept along and are eliminated as the cause of the magnetohydrodynamic instabilities. To realize an Alfven black hole, it is proposed to bring a plasma into rapid rotation through radially arranged lumped parameter transmission lines intersecting the plasma under an oblique angle, with the rotational velocity exceeding the Alfven velocity. The rotating plasma slides frictionless over magnetic mirror fields directed towards the rotating plasma, with the mirror fields generated by magnetic solenoids positioned at the end of each transmission line. It is then shown that, with this configuration one can realize a thermonuclear dynamo, which also can serve as the analogue of a magnetar.

YP8.00007 Global Plasma Oscillation Regime and Its Suppression on TCV
, ELINA ASP, VICTOR UDINTSEV, TIMOTHY P. GOODMAN, OLIVIER SAUTER, GIANPAOLO TURRI, Ecole Polytechnique Federale de Lausanne, Centre de Recherches en Physique des Plasmas, Association Euratom Confederation Suisse, CH-1015 Lausanne — In the Tokamak à Configuration Variable (R/a = 0.88 m/ 0.24 m, $B_T < 1.54$ T), global plasma oscillations are found to exist in fully non-inductive plasmas featuring eITBs with strong ECRH/ECCD. This phenomenon is akin to the so-called Oscillatory, or O-regime, first observed in LHCD plasmas on Tore Supra. In TCV, the O-regime is linked to the evolution of the MHD modes in the reversed magnetic shear plasmas. It is demonstrated that the O-regime can be effectively suppressed by ECCD-induced local cur-rent density perturbation or by adding an Ohmic current perturbation. In these experiments MHD activity is modified through current density profile tailoring rather than local deposition within an island. The suppression of the O-regime usually leads to improved energy confinement, which is characterized by exceeding the Rebut-Lallia-Watkins scaling, to obtain H_{RLW} above 3.5. The detection of the MHD modes by various diagnostics (ECE, SXR, Mirnov coils etc) has aided in the correct identification of rational q-surfaces and in understanding their role in the evolution of the O-regime. The evolution of the safety factor during the O-regime has been studied by means of CQL3D/ASTRA simulations and will be presented.

YP8.00008 Ratchet and curvature pinch in turbulent plasmas
, MADALINA OLIMPIA VLAD, FLORIN SPINEANU, National Institute of Laser, Plasma and Radiation Physics, SADDRUDIN BENKADDA — We have shown that the gradient of the confining magnetic field, grad(B), generates a pinch (average velocity) in turbulent plasmas. It is a ratchet type process that appears in test particle approach due to the modification of guiding center trajectories. The ratchet pinch depends on the characteristics of the turbulence and changes its orientation along grad(B) from anti-parallel to parallel when trajectory trapping or eddying appears. Another effect of grad(B) is the compressibility of the ExB velocity field, which was shown to produce a pinch parallel with grad(B), the curvature pinch. The influence of grad(B) on trajectories is neglected in the derivation od the curvature pinch. We determine here the evolution of particle density taking into account both effects. We include in the model particle collisions and plasma rotation and determine their effects on the transport and on the peaking factor. The results are compared with the experimental data on impurity transport in tokamak plasmas.

YP8.00009 Convex optimation of a pulsed inductive plasma thruster model
, SAM ADHIKARI, Sysoft, R&D Division of Integratise Inc. — Exhaust velocity and efficiency are represented as a function of nondimensionalized set of coupled circuit equations and a momentum equation in a pulsed inductive plasma thruster model. Convex optimization techniques are used to maximize efficiency and to determine the optimal criteria. Statistical estimation techniques are used to optimally match the acceleration timescale to circuit's natural period. Vector optimization techniques allow the estimation of optimal fraction of the propellant loaded near the inductive acceleration coil to maximize performance.

YP8.00010 Assessment of the LiWall plasma regime for DD fusion[1] , LEONID E. ZAKHAROV, Princeton University, PPPL, ENGLEN A. AZIZOV, TRINITI, RF, JOHN SHEFFIELD, University of Tennessee — The lithium plasma facing components pump out the plasma particles and eliminate the cold particles, which enter it in the conventional wall situation. Together with core plasma fueling by neutral beam injection this provides flat plasma temperature, eliminates the turbulence associated with the temperature gradient, and leads to the best possible confinement regime. The Reference Transport Model (RTM), which assumes all transport coefficients equal to the ion thermo-conductivity $\chi_i = \chi_e = D = \chi_i^{neo}$ can describe the LiWall confinement quantitatively. Implementation of the LiWall regime would make the path to the DT fusion straightforward. It is only the inability of the current fusion program to move beyond the outdated concept, which prevents the progress in DT fusion with the LiWall regime. In this regime, at a given beta, the confinement $\tau_E \propto T^{3/2}$ is very favorable for DD fusion as well. The question, studied here using the RTM, is if it is possible to maintain the plasma in the hot-ion mode by NBI, while expelling the fusion products and keeping the radiation from electrons limited. Realization of DD fusion could be of great interest because of its independence from tritium fuel and possible use for transmutation of radioactive waste.

[1]Supported by US DoE contract No.DE–AC020–76–CHO–3073

YP8.00011 The theory of the failure of magnetic fusion[1] , LEONID E. ZAKHAROV, Princeton University, PPPL — In the physics of the 20th century, fusion represents an extraordinary failure which eroded expectations of society on an "unexhaustible" energy source. The question is if these 50 years of research did really prove that fusion will be forever a "carrot" on a stick and always 35 years from its implementation. When a person is asking fusion people why this program is full of broken promises, he (besides conventional complaints on the lack of funding) is typically getting the answer that the problem itself is the most difficult one that physics ever faced. In the FSU, such characterizations were done as early as in the 60s by Lev Artsimovich, the leader in the field. This view is only partially applicable in the 21st century. Since the times of Artsimovich, fusion, as a "difficult" problem, has been converted into the "complicated" one. The presented theory makes a clear distinction between these two kinds of problems, which require significantly different management approaches, and explains the current stagnation in magnetic fusion by the lack of understanding this crucial difference.

[1]Supported by US DoE contract No.DE–AC020–76–CHO–3073

YP8.00012 Dynamic hohlraums as x-ray sources in high-energy density science[1] , J.F. HANSEN, S.G. GLENDINNING, R.F. HEETER, Lawrence Livermore National Laboratory — A new laser driven dynamic hohlraum (LDDH) backlighter has been evaluated using 10 of 60 beams of the Omega laser. The LDDH is filled with krypton that implodes to create an x-ray flash that satisfies requirements imposed by future experiments: (1) the flash spectrum extends > 5.5 keV, well above the maximum x-ray energy (∼3.5 keV) obtained from the previously "best" opacity backlighters (uranium M-shell emission backlighters); (2) the spectrum is smooth and featureless (intensity variation <6% RMS), allowing absorption spectrometry through experimental samples; (3) the flash size is sufficiently small (<50 μm) for projection backlighting through future samples; (4) the flash is bright enough (and twice as bright as imploding hydrogen-filled capsules) for gated spectrometer measurements; and (5) the flash duration is optimized (≈100 ps) for current and future generations of spectrometers. This enables opacity and temperature measurements through absorption spectrometry of materials in LTE at temperatures >150 eV, a crucial regime for future astrophysics and ignition fusion experiments at NIF.

[1]This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

YP8.00013 Theoretical approach to the ground state of spherically confined Yukawa plasmas[1] , CHRISTIAN HENNING, MICHAEL BONITZ, ITAP, University of Kiel, ALEXANDER PIEL, IEAP, University of Kiel, PATRICK LUDWIG, HENNING BAUMGARTNER, ITAP, University of Kiel — Recently spherical 3D dust crystals (aka Yukawa balls) were discovered [1], which allow direct observation of strong correlation phenomena and the structure of which is well explained by computer simulations of charged Yukawa interacting particles within an external parabolic confinement [2]. Here we present an analytical approach to the ground state of these systems using the minimization of the system's energy. Applying the non-local mean-field approximation we show that screening has a dramatic effect on the density profile, which can be derived explicitly [3]. In addition the local density approximation allows for the inclusion of correlations, which further improves the results in the regime of large screening [4]. Comparisons with MD simulations of Yukawa balls show excellent agreement.

[1] O. Arp et al. Phys. Rev. Lett. 93, 165004 (2004)
[2] M. Bonitz et al., Phys. Rev. Lett. 96, 075001 (2006)
[3] C. Henning et al., Phys. Rev. E 74, 056403 (2006)
[4] C. Henning at al., Phys. Rev. E (2007)

[1]Support by the DFG (via SFB-TR24) is acknowledged

YP8.00014 Stability of Ultrathin Solid Targets in the Radiation Pressure Dominated Regime with Circular Polarization , C. BELLEI, R.G. EVANS, Imperial College London, S. ATZENI, La Sapienza, Rome, A.P.L. ROBINSON, Rutherford Appleton Laboratory, S. KAR, M. ZEPF, Queens University of Belfast — The stability of ultrathin (thickness << laser wavelength) solid targets illuminated by circularly polarized laser pulses is studied in a regime where the radiation pressure is the dominant acceleration mechanism, by means of 2D3V PIC simulations (Osiris code). The Osiris simulations show that the foil exhibits an instability very similar to the classical Rayleigh-Taylor instability even though the foil material is not collisional. Indeed, it is found that the mechanism of ion bunch formation leads to the growth of unstable modes that become nonlinear in a few laser cycles and have a detrimental effect for the production of monoenergetic ions. The possibility of tailoring the laser intensity profile in order to inhibit the bunch formation and therefore decrease the growth of the instability will be also discussed.

YP8.00015 Perturbation Theory For A Maximal Gyrokinetic Ordering[1] , A.M. DIMITS, Lawrence Livermore National Laboratory, AND THE ESL TEAM — We develop a perturbation theory for a maximal gyrokinetic ordering. By working with a lowest-order gyrocenter position variable that is relative to the aggregate local ExB displacement, and a particular gauge condition for the electromagnetic (4-)potential, the Poincare-Cartan 1-form can be cast in such a way that its perturbed parts depend on the electric-field shear and time derivative, and not directly on the electrostatic field nor the potential. This permits the perturbation theory to be carried out in an optimal ordering in which the small parameter is the change in local ExB velocity across a particle's gyro-orbit divided by its perpendicular velocity (or the relative orbit squeezing parameter), and which does not necessitate any separation of the electrostatic potential into equilibrium and perturbed parts. Existing results (Hahm '96; Qin et. al., 2006-2007) can be obtained via subsidiary orderings.

[1]Work performed for USDOE by Univ. California LLNL under contract W-7405-ENG-48.

YP8.00016 Simulation studies of FRC with rotating magnetic field current drive [1] , E.V. BELOVA, R.C. DAVIDSON, PPPL — The HYM code has been modified to include the effects of rotating magnetic field (RMF) current drive. Initial 3D two-fluid and hybrid simulations have been performed for even-parity RMF and different plasma parameters. Simulations show that the RMF pushes the plasma radially inward, resulting in a reduced plasma density outside the separatrix. Lower plasma density and larger RMF amplitudes result in faster RMF field penetration, in agreement with previous studies [R. Milroy, Phys. Plasmas 8, 2804 (2001)]. Effects of the applied RMF field on particle confinement have been studied using 3D test particle simulations. Simulations of stationary RMFs show that for relatively large ion Larmor radius ($S^* < 20$), there is very little difference between even- and odd-parity RMFs in terms of the ion losses. The rate of particle losses is larger in larger FRCs, and increases with the RMF amplitude. In contrast, high-frequency RMF can reduce ion losses provided $\omega_{rmf} \gg \omega_{ci}$, and the RMF is of even-parity. The improved particle confinement is related to ponderomotive forces due to the rapidly oscillating, inhomogeneous electromagnetic field. It is also found that high-frequency, odd-parity RMFs force particles away from the midplane toward the FRC ends.

[1]Supported by DE-AC02-76CH03073.

YP8.00017 A Vertical ECE Diagnostic for TCV [1] , L. PORTE, S. CODA, S. ALBERTI, R. BERTIZZOLO, R. CHAVAN, J-M. MAYOR, V. UDINTSEV, Ecole Polytechnique Federale de Lausanne (EPFL), Centre de Recherches en Physique de Plasmas, Association EURATOM Confederation Suisse, 1015 Lausanne, A. SIMONETTO, Instituto di Physica del Plasma, Associazione EURATOM-ENEA-CAN, Via Cozzi 53, 20125 Milano, Italy — With ECRH power density unrivalled in the fusion community, TCV is in a unique position to study fast-electron dynamics in regimes where quasi-linear effects dominate. TCV is equipped with a comprehensive suite of ECE heterodyne radiometers that covers the first three ECE harmonics. A new vertical line of sight will be installed which will allow measurements to be made whose interpretation is straightforward and yields direct information on the fast electron energy distribution. The line will be equipped with a glass ceramic (MACOR) beam dump mounted in the vacuum vessel while the focussing optics will be placed in air behind a quartz window. An oversized, corrugated transmission line will transport the radiation from the tokamak to the radiometers. The diagnostic layout and the physics potential will be described.

[1]Work partially supported by the Fonds National Suisse de la Recherche Scientifique.

YP8.00018 An Improved Collision Algorithm for Explicit and Hybrid Implicit PIC Simulations , LARISSA A. COTTRILL, ANDREAS KEMP, MAX TABAK, Lawrence Livermore National Laboratory — Since its acclimation from the ion beam community, the LSP code has been used to model a wide range of laser-plasma configurations relevant to fast ignition research. Given the high density, low temperature regimes of interest for some of these problems, there has been an increased concern for the role collisionality might play in hot electron beam transport and how one would appropriately model this in an electromagnetic hybrid-implicit particle-in-cell code such as LSP. Although a number of scattering models exist in the literature and in practice, there are always underlying concerns for computational efficiency and kinematic accuracy. This work will present a new collision algorithm for the LSP code that will improve upon the inter- and intra-species collision algorithms that currently exist within the code. Comparisons between various aspects of the old and new models will be presented for several beam-plasma problems of interest. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

YP8.00019 Evolution of Non-gyrotropic Pressure in Collisionless Magnetic Reconnection [1] , HAIHONG CHE, J. DRAKE, M. SWISDAK, University of Maryland — From the view of statistics, we separate the non-gyrotropic pressure into two multiplied parts: the gyrotropic pressure and the correlation function in particle velocity space. The gyrotropic pressure is related to the heating process. The correlation is determined by the chaotic motion at x-line or by the turbulent process, which depend on the type of the instabilities. We perform both 3D low and high temperature magnetic reconnection particle simulations. The low temperature develop a Buneman instability around x-line while the turbulence is absent in the high temperature simulation. Our simulations show that 1) the resonant chaotic motion occur at x-line while the width of electron current sheet is in the order of electron Lamour radius, which build up a significant correlation in electron velocity space. The contribution to correlation from the turbulence is small because the instabilities occur in our simulation are uncorrelated in the non-gyrotropic space. 2) The anomalous heating also enhance the role of non-gyrotropic pressure . The heating caused by turbulence is much more effective than the heating caused by the chaotic motion.

[1]NASA and NSF

YP8.00020 1 D analysis of Radiative Shock damping by lateral radiative losses. , MICHEL BUSQUET, LERMA-Observatoire de Paris & ARTEP, Inc, JEAN-PHILIPPE COLOMBIER, CHANTAL STEHLE, LERMA-Observatoire de Paris — It has been shown theoretically and experimentally [1] that the radiative precursor in front of a strong shock in hi-Z material is slowed down by lateral radiative losses. The 2D simulation showed that the shock front and the precursor front remain planar, with an increase of density and a decrease of temperature close to the walls. The damping of the precursor is obviously sensitive to the fraction of self-emitted radiation reflected by the walls (the albedo). In order to perform parametric studies we include the albedo controlled lateral radiative losses in the 1D hydro-code MULTI (created by Ramis et al [2]) both in terms of energy balance and of spectral diagnostic.

[1] Gonzales et al, Laser Part. Beams 24, 1-6 (2006) ; Busquet et al, High Energy Density Physics (2007), doi: 10.1016/j.hedp.2007.01.002
[2] Ramis et al, Comp. Phys. Comm., **49** (1988), 475

YP8.00021 Beam plasma electromagnetic instabilities in a smooth density gradient:Applications to ICF fast ignition , ANTOINE BRET, ETSII UCastilla-la-Mancha, CLAUDE DEUTSCH, LPGP UParis XI, BRET COLLABORATION — We detail a calculation of the integrated growth rate(GR) of an instability in a weakly varying plasma density gradient using a WKB-like approximation.We justify such an assumption in the fast ignitor scenario context.Our formalism includes 2- stream, filamentation and 2-stream/filamentation instabilities.The latter features an appropriate mixture of the separate two former ones.It is also the fastest.We demonstrate that filamentation is damped through the density gradient whereas 2-stream and 2-stream/filamentation saturate even before being submitted to the density gradient.

YP8.00022 Structural transitions in spherical 3D screened Coulomb crystals[1] , MICHAEL BONITZ, DANIEL ASMUS, VOLODYMIR GOLUBNICHIY, HENNING BAUMGARTNER, PATRICK LUDWIG, ITAP, University of Kiel — After the first observation of 3D Coulomb crystals [2], the particularly interesting structures of spherical concentric shells were found in experiment and simulations [3], and it was then demonstrated that the Coulomb interaction between the dust particles is screened [4]. Here, we extend this work by performing extensive molecular dynamics simulations to calculate the ground states of mesoscopic Coulomb balls ($N \leq 60$) in a wide range of screening parameters. The ground states interesting structural transitions, such as the changes of the shell population with the screening parameter as well as the particle number. We present a phase diagram where a general trend to increased inner shell populations with increased screening can be seen.

[1] R. W. Hasse et al., Phys. Rev. A 44, 4506 (1991)
[2] O. Arp et al., Phys. Rev. Lett. 93, 165004 (2004)
[3] P. Ludwig et al., Phys. Rev. E 71, 046403 (2005)
[4] M. Bonitz,et al., Phys. Rev. Lett. 96, 075001 (2006)

[1]This work is supported by the DFG via SFB-TR24.

YP8.00023 Diamagnetic loop for KSTAR.[1] , JUN-GYO BAK, SANG-GON LEE, EUN-MIE KA, National Fusion Research Center — Three sets of diamagnetic loop (DL), at different locations, are designed to measure diamagnetic flux during a plasma discharge in the KSTAR machine. Each set consists of two concentric poloidal loops, and it is used for the diamagnetic flux measurement with the compensation of a ripple from to the power supply producing a toroidal field and a pick-up signal from the poloidal field due to the misalignment in the installation. One set is installed on inner wall of the vacuum vessel for the flux measurement at the first plasma in the KSTAR machine. It is located at a toroidal angle in the vacuum vessel, and the gap distance between inner and outer loops is 2 cm. An accurate position measurement of the two loops is done by using a laser tracker system after the installation. The *in-situ* calibration of the loops is done from the toroidal flux measurement. In the measurement, the electric current of less than 100A is applied to the toroidal field coils. In this work, present status of the DL for the initial measurement in the KSTAR machine will be presented.

[1]Work supported by the Korea Ministry of Science and Technology under the KSTAR project contract.

YP8.00024 Mix Calculations of Double-Shell capsule implosions on Omega and NIF , N.D. DELAMATER, G.R. MAGELSSEN, M.A. GUNDERSON, D.C. WILSON, I.L. TREGILLIS, Los Alamos National Lab — Recently, Los Alamos has renewed its effort [1] to design and evaluate double-shell capsules as an alternative to the single-shell cryogenic NIF design. [2] The recent work by Livermore is being used as a starting point. [3-4] One to two megajoules of laser energy is used as input into the designs being considered. 1D and 2D integrated calculations of both the NIF capsule design and the double-shell design recently fielded on Omega will be presented. The unmixed calculations for a NIF design give ignition with moderate gain < 10. Calculations of the Omega double shell design are shown and application of the Omega experiments to the scaled up NIF double shell ignition design is discussed. Sensitivity to mix effects in these implosions with respect to overall yield, implosion hydro, asymmetry and imploded capsule core x-ray emission is investigated using a multi-fluid interpenetration model. [5,6] Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396 [1] W. S. Varnum et al., Phys. Rev. Lett. 84, 5153 (2000). [2] D. A. Callahan et al., Phys. of Plasmas 13, 56307 (2005). [3] P. A. Amendt et al., Phys. Rev. Lett. 94, 65004 (2005). [4] J. L. Milovich et al., Phys. of Plasmas 11, 1552 (2004). [5] A.J. Scannapieco and B. Cheng, Phys. Lett. A., 299, 49 (2002). [6] D.C. Wilson, et al., Phys. of Plasmas 11, 2723 (2004)

YP8.00025 Simulation Studies of the Pulse Line Ion Accelerator[1] , ENRIQUE HENESTROZA, ROXANNE MARTINEZ, LBNL — The Heavy Ion Fusion Science Virtual National Laboratory has been studying the Pulse Line Ion Accelerator (PLIA) concept, motivated by the desire for an inexpensive way to accelerate intense short pulse heavy ion beams to regimes of interest for studies of high energy density matter and fusion ignition conditions. The PLIA uses a slow-wave structure based on a helical winding, on which a voltage pulse is launched and propagated to generate the accelerating fields. The PLIA has the ability to accelerate ion bunches to energies much greater than the peak applied voltage and over distances much larger than the voltage pulse ramp length; furthermore, the PLIA can axially confine the heavy ion beam bunch. These properties make it a good candidate for a high intensity, short bunch injector. We will present self-consistent numerical simulation studies of the beam dynamics in the PLIA.

[1]This research was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231

YP8.00026 Simulations of Radiation Flow in Inhomogeneous Foams , M.A. GUNDERSON, P. KEITER, Los Alamos National Laboratory, J. FOSTER, P. ROSEN, A. COMLEY, M. TAYLOR, AWE — Radiation flow through inhomogeneous materials has been of great interest in many areas, including astrophysics applications. However, experiments to study this phenomenon have proven very challenging. The experiment is made up of a scale-one OMEGA halfraum with an attached gold tube filled with various foam-gold mixtures or pure foams. While we have had success in modeling the pure foam and the fine gold particle (less than 0.5 micron) "atomically" loaded foams, M-band radiation from the halfraum was preheating the inhomogeneous mixture. By increasing the gold particle sizes from 1-2 microns up to 5-9 microns, it appears that this problem has been mitigated. Gated x-ray imagers filtered to look at both 300 and 500 eV spectral bands were used as the primary diagnostic in determining the location of the temperature front through diagnostics slots in the gold tube. Comparisons between experimental data and simulations will be shown with the pure foam and "atomically" loaded foam-gold mixtures as the bounding cases. Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

YP8.00027 A Unified Theory of Toroidal Momentum Transport and Momentum Transport Bifurcations by Drift Wave Turbulence[1] , P.H. DIAMOND, C. MCDEVITT, O.D. GURCAN, University of California, San Diego, La Jolla, CA 92093-0424 USA, T.S. HAHM, Princeton Plasma Physics Laboratory, Princeton, NJ 08543-0451 USA, V. NAULIN, Risoe National Laboratory, Roskilde, DK-4000, Denmark — We present a unified theory of toroidal momentum transport, treating both resonant and non-resonant particle contributions. A general momentum conservation theorem is proved, which relates momentum density evolution to the resonant particle momentum flux, the wave momentum flux and a refractive force due to straining of wave packets. The wave momentum flux is calculated using a Chapmen-Enskog like expansion of the wave kinetic equation. The results are used to explain a new class of momentum transport bifurcation. Possible origins of hysteresis are discussed.

[1]This work was supported by DoE Grant No. DE-FG02-04ER54738.

YP8.00028 Low velocity ion stopping of relevance to the US beam-target program , CLAUDE DEUTSCH, ROMAIN POPOFF, LPGP UParis XI, DEUTSCH COLLABORATION — We focus attention on the stopping mechanisms involved in the recently proposed US beam-target program devoted to the production of warm dense matter through pulsed ion beams linearly accelerated and impacting thin solid foils in Bragg peak conditions.We concentrate on moderate or low ion projectile velocities Vp $<$ Vth, target thermal electron velocity. Ion projectile energy loss in the very low and Vp- linear regime is investigated in a novel and statistical physics approach in terms of particle diffusion coefficients. Beam target interaction in the presence of an arbitrarily strong magnetic field is also considered.

YP8.00029 Using Half of NIF to Tune Full-Scale Ignition Hohlraums[1] , NELSON HOFFMAN, DOUGLAS WILSON, ROBERT GOLDMAN, LANL — If fusion ignition is to be achieved at NIF, the symmetry of drive radiation incident on the ignition capsule must be superb. Thus techniques for diagnosing and verifying drive symmetry are highly important. Here we describe how half of the NIF facility (i.e., only 96 laser beams, expected to be available in 2008) can be used to tune drive symmetry in full-scale ignition hohlraums during the first several steps (the "foot") of the ignition pulse, in a manner similar to what will be done with full 192-beam NIF. This is possible because the foot requires less than half of the energy and power NIF can deliver, so half the beams each running at twice the power can deliver the full-scale energy during the foot, although not during the final, highest-power step. Only modest compromises are necessary due to the slightly different illumination geometry with 96 beams. We propose a set of symmetry capsules imploding at properly chosen times, allowing foot tuning by beam phasing, thus expediting final foot tuning with 192 beams.

[1]Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

YP8.00030 An advanced X-ray imaging crystal spectrometer for tokamak plasmas , SANG GON LEE, JUN KYO BAK, MIN GAP BOG, National Fusion Research Center, UK WON NAM, Korea Astronomy & Space Science Institute, MYUNG KOOK MOON, JONG KYU CHEON, Korea Atomic Energy Research Institute — An advanced X-ray imaging crystal spectrometer (XICS) utilizing a segmented position-sensitive two dimensional (2D) multi-wire proportional counter and time-to-digital converter (TDC) based delay-line readout data acquisition system is under development. The XICS provides spatially and temporally resolved measurements of the ion and electron temperatures, toroidal rotation velocity, impurity charge-state distributions, and ionization equilibrium. Recently, a proto-type of two-segmented detector with a F1 chip TDC based delay-line readout and supporting electronics successfully demonstrated to improve the photon count-rate capability of the XICS system. Based on this improvement, further developments including four- and eight-segment detectors and supporting electronics are possible. Furthermore, a vacuum brazing technique for a small thin beryllium window has been successfully developed. This vacuum brazing technique will be applied to the detector development in order to increase detector performances as compared to the typical epoxy-bonding method. The current development status of the advanced X-ray imaging crystal spectrometer will be presented.

YP8.00031 PIC simulations of cone surface roughness and angle dependence in high intensity laser/micro-cone interaction , NATHALIE LE GALLOUDEC, EMMANUEL D'HUMIERES, University of Nevada, Reno, Reno NV 89557, BYOUNG ICK CHO, JENS OSTERHOLZ, TODD DITMIRE, University of Texas, Austin, Austin TX 78712, YASUHIKO SENTOKU, University of Nevada, Reno, Reno NV 89557 — It has been recently demonstrated that compared to a typical flat target, micro-cone targets can increase laser energy absorption and energetic electrons temperature when irradiated by a high intensity laser. These increases are very promising for numerous applications of high intensity laser plasma interaction, like proton acceleration or isochoric heating. Using Particle-in-Cell simulations, we have analyzed the role of cone surface roughness and cone angle in changing the characteristics of the produced energetic electrons population. Our results are compared to experiments done at UT Austin with the Thor laser (0.5 J, 40 fs, 800 nm, 7 microns focal spot). Based on these results, we propose new micro-cone designs to increase the efficiency of laser energy deposition.

YP8.00032 Modelling of hydrodynamics instabilities including the non local heat transport , MARINA OLAZABAL-LOUME, CELIA Universite Bordeaux I , France, JEAN-LUC FEUGEAS, PHILIPPE NICOLAI, CELIA Universite Bordeaux I, France, JAVIER SANZ, ETSI, Aeronauticos, Univ. Polytechnica Madrid, Spain — Experimental works [T. Sakaiya *et al.*, Phys. Rev. Lett. 88, 145003 (2002)] have shown that the growth rate of ablative Rayleigh-Taylor instability is well reproduced by the simulation that solves the nonlocal heat transport. Furthermore, it has been recently pointed out [V. N. Goncharov *et al.*, Phys. Plasmas 13, 012702 (2006)]that non local heat transport modifies characteristic lengths needed in hydrodynamic instabilities models. This work presents a new way to take into account the non local effects in hydrodynamic instabilities modelling. The simulations are performed with a code dedicated to the linear stability study of unsteady flows [M. Olazabal-Loumé *et al.*, J. Phys. IV France 133 (2006)]. The code calculates a one-dimensional basic solution and its first order 3D perturbation in Lagrangian formalism. It integrates a multidimensionnal non local model based on the approach of [J-F. Luciani *et al.*, Phys. Rev. Lett. **51**, 1664 (1983)] and [E. Epperlein et al., Phys. Fluids B **3**, 3082 (1991)].

YP8.00033 Transition From Two-Fluid to Resistive MHD Tearing Instability in Slab and Cylindrical Geometries , V.V. MIRNOV, A. COLE, C.C. HEGNA, S.C. PRAGER, University of Wisconsin - Madison, Center for Magnetic Self Organization in Laboratory and Astrophysical Plasmas — We report new results on the physics of two-fluid tearing instabilities with particular focus on analytically understanding the transition between the two-fluid and single-fluid MHD regimes. Linear eigenfunctions and quasilinear dynamo terms are calculated in both slab and cylindrical geometry with specific emphasis on edge-resonant m=0 tearing modes in the Madison Symmetric Torus (MST) reversed field pinch experiment. A two-fluid quasilinear theory was originally derived for a sheared slab in [1] and generalized to cylindrical geometry in [2], where the effects of current gradient and field line curvature were analyzed in the electron MHD approximation. To investigate the transition between the different regimes, we extend the previous work to include the effects of ion motion. This allows us to analytically follow the transition from a two-fluid to single-fluid regime. The growth rates and eigenmode profiles are obtained to allow comparison with two-fluid MHD codes, and for interpretation of recent MST measurements of Hall reconnection. *Supported by the U.S.DoE and NSF. [1] V. V. Mirnov, C. C. Hegna, S. C. Prager, Plasma Physics Report 29, 612 (2003) [2] V.V. Mirnov, C.C. Hegna, S.C. Prager, C.R. Sovinec, H. Tian, Proc. of 21st IAEA FEC, Chengdu, China, TH/P3-18 (2006)

YP8.00034 Designs for subscale hohlraum energetics experiments on the National Ignition Facility[1] , N.B. MEEZAN, D.A. CALLAHAN, M.J. EDWARDS, D.E. HINKEL, B.K. SPEARS, S.H. GLENZER, L.J. SUTER, Lawrence Livermore National Laboratory — The 96-beam energetics campaign on the National Ignition Facility will use subscale targets to emulate the plasma conditions and laser-plasma interaction (LPI) behavior of ignition hohlraums. These "plasma emulator" targets are geometrically scaled by a scale-factor s. To lowest order, the laser pulse shapes are also directly scaled (time $t \propto s$ and power $P \propto s^2$); however, fine-tuning the pulse can improve the hohlraum emulator quality. The plasma density inside the hohlraum depends strongly on the mass ablated from the capsule during the foot, so we try to match this to the ignition value, $m_{96}(t) = s^3 m_{ignition}(st)$. Matching the ablated mass leads to ignition-like hohlraum plasma conditions. Linear gain analysis predicts LPI behavior in the emulator hohlraum that is qualitatively and quantitatively similar to that of an ignition hohlraum.

[1]This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

YP8.00035 Three-dimensional measurements of early-time symmetry in gas-filled hohlraums with the reemission ball technique , G.R. MAGELSSEN, N.D. DELAMATER, Los Alamos National Laboratory, J.J. MACFARLANE, Prism Computational Sciences, O.L. LANDEN, Lawrence Livermore National Laboratory — The reemission ball technique has been used in the past to measure early time capsule symmetry for experiments done on NOVA.[1-2] Livermore scientists are now pursuing this concept to study early time symmetry on NIF.[3] Here we review some unpublished results using this method.[4] The results include reemission measurements in methane-filled hohlraums irradiated by lasers with kinoform phase plates. They also include three- dimensional measurements of asymmetries due to beam power imbalance and from diagnostic holes. Comparisons between experimental data and calculations will be shown. New results will also be presented. Reemission measurements made within spherical hohlraums will be shown. Finally, a method used to increase the time of the reemit measurement will be discussed and experimental results given. 1. G. R. Magelssen et al., Phys. Rev. E 57, pg. 4663 (1998). 2. N. D. Delamater et al., Phys. Rev. E 53, 5240 (1996). 3. Don Meeker, J. Edwards, private communication, LLNL. 4. G. R. Magelssen et al., Abstract 1998 APS meeting; G. R. Magelssen et al., "Three-Dimensional measurements of early time radiation asymmetry in methane-filled hohlraums," LA-UR-07-3742.

YP8.00036 An explicit Hall MHD algorithm using the discontinuous Galerkin method , JOHN LOVERICH, Tech-X Corporation — The discontinuous Galerkin method is a numerical wave propagation scheme that can achieve arbitrarily higher order accuracy. The method has received considerable attention from the numerical fluid dynamics community recently. In this paper an explicit discontinuous Galerkin Hall MHD algorithm is presented. The algorithm works in the high beta regime and can be used to simulate collisionless reconnection and fast instabilities in a Z-pinch. Error wave propagation is used to correct divergence errors. The scheme uses auxiliary variables to treat the higher order derivatives that result from the Hall and diamagnetic drift terms. Hall MHD results are compared with full two-fluid results and show good agreement. The explicit scheme is a first step in producing an implicit discontinuous Galerkin algorithm that does not suffer the time step restriction of the Whistler wave.

YP8.00037 Development of Generator of High-Velocity Gas Jet by using a Compact Toroid Injector , D. LIU, N. FUKUMOTO, University of Hyogo, T. TAKAHASHI, Gunma University, J. MIYAZAWA, National Institute for Fusion Science, Y. KIKUCHI, M. NAGATA, University of Hyogo — Fueling expreiments by supersonic gas jets has been conducted on several tokamaks. The ability of gas jets, however, is not enough to penetrate into the plasma core. Rozhansky et al have proposed a new technique for acceleration of jet by a plasma gun to enhance the ability [1]. The jet has been successfully accelerated to 100 km/s, resulting in penetration into the plasma core on Globus-M. We have so far developed compact toroid (CT) injectors as a kind of plasma gun, and performed CT injection experiments. We have therefore considered generation of such a gas jet by using a CT injector. The preliminary experiment has been carried out to generate fast gas jets by CT injection into a plasma neutralizer cell with a single-stage CT injector at the University of Hyogo. The typical CT parameters are: 1$\sim$4 x 10^{21} m^{-3} in electron density and 30$\sim$70 km/s in velocity. The neutralization efficiency of CT plasma has been also estimated by calculation. The technique will be applied to a CT injector of SPICA for an advanced fueler into LHD.
[1] V. Rozhansky et al, Proc. 33rd EPS Conf. on Plasma Phys., Roma, 2006, 30I, P-4.107 (2006).

YP8.00038 Platform development of x-ray absorption-based temperature measurements above 100-eV on the OMEGA laser[1] , JONATHAN WORKMAN, P. KEITER, T. TIERNEY, H. TIERNEY, K. BELLE, G. MAGELSSEN, R. PETERSON, C. FRYER, Los Alamos National Laboratory, A. COMLEY, M. TAYLOR, Atomic Weapons Establishment — Experiments were performed on the OMEGA laser system at the University of Rochester to measure radiation temperature in hohlraum-heated foams. Using x-ray absorption spectroscopy in the 3-6-keV x-ray range allows temperature determination in the range of 50-200-eV. Uranium, bismuth and gold M-shell x-ray emission were used as broadband backlighters. Backlighter absorption through heated chlorinated foam and scandium tracers were used to determine temperatures. The development of this technique in the temperature range of 100-200-eV will be used for platform development of future NIF experiments. We will present time-integrated and time-resolved measurements of x-ray emission from the backlighter materials as well as absorption measurements trough the heated tracer materials. We will also present future directions in the development of this platform.

[1]Work performed under the auspices of the Dept. of Energy under contract #DE-AC52-06NA25396

YP8.00039 Sensitivity of Double-Shell Ignition Capsules to Asymmetric Drive[1] , I.L. TREGILLIS, G.R. MAGELSSEN, N.D. DELAMATER, M.A. GUNDERSON, N.M. HOFFMAN, Los Alamos National Laboratory — Double-shell (DS) targets [1] present an alternative approach to ignition via the cryogenic single-shell point design [2]. Although these targets present unique fabrication challenges, they embody many attractive features, including non-cryogenic fielding and low threshold temperatures ($\sim$4 keV) for volume ignition [3-4]. We have used 2D radiation-hydrodynamic modeling to survey the behavior of DS targets under asymmetric temperature drive in rugby vacuum hohlraums. The yield is robust against deviations from symmetric illumination, varying smoothly as a function of the imposed P_2 and P_4 amplitudes. Ignition occurs even when 10% or more of the drive is contained in Legendre P_2 or P_4 components, with yield reductions on the order of 50% for the most extreme cases investigated here.
[1] P. Amendt et al., Phys. of Plasmas 9, 2221 (2002)
[2] D. A. Callahan et al., Phys. of Plasmas 13, 56307 (2005)
[3] P. Amendt et al., Phys. Rev. Lett. 94, 65004 (2005)
[4] W. S. Varnum et al., Phys. Rev. Lett. 84, 5153 (2000)

[1] Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

YP8.00040 Suppression of Weibel Instabilities in Advanced Fast Ignition Laser Fusion Pellets by Two Cone-Guided Relativistic Laser Beams[1] , V. STEFAN, Nikola Tesla Laboratories, Stefan University, 1010 Pearl, La Jolla, CA 92038-2946 — I propose utilization of two cone-guided relativistic laser beams in antiparallel interaction with the fusion pellet as a novel approach for the suppression of Weibel instabilities in the core of advanced fast ignition pellets.[2] The propagation of generated suprathermal electron beam toward the core may lead to the appearance of colossal ($\sim$10MG), small scale (L$\sim$velocity of light/local electron plasma frequency[3] magnetic fields. This would suppress the transport of magnetic fields into the core of the pellet and may eliminate the difficulties in the nonlinear-relativistic treatment of magnetized core plasma.

[1]Supported by Nikola Tesla Laboratories, La Jolla, CA 92038-2946.

[2]M. Tabak, J. Hammer, M.E. Glinsky, W.L. Kruer, S. C. Wilks, J. Woodworth, E. M. Campbell, and M.D. Perry, Phys. Plasmas 1 (5), 1626 (1994).

[3]V. Stefan, Suppression of Weibel Instabilities by High-Harmonic Electron Bernstein Modes in Advanced Fast Ignition Laser Fusion Pellets.APS-2006. October 30-November 3, 2006; Philadelphia, Pennsylvania.

YP8.00041 Dose Prediction in Plasma Ion Implantation[1] , MARCEL RISCH, MICHAEL BRADLEY, University of Saskatchewan — The exact knowledge of the plasma ion current, and hence the implanted dose, is essential for materials processing, but the measurement of those quantities requires complex instrumentation. We present the computation of the ion current and dose from the sampled negative voltage pulse applied to the electrode and plasma parameters obtained by virtue of Langmuir probe measurements. Firstly, we solved the equations of the Lieberman model for the sheath width and the plasma ion current, including errors, as a function of time. Then, integration of the ion current over the duration of the voltage pulse yielded the dose and its error limits. We will compare the plasma current predictions to the plasma current measured by a Faraday cup and the dose calculation will be verified by nuclear reaction analysis (NRA). The numerical methods were proven fairly accurate and are thus a valuable tool for materials engineering.

[1]This work is being supported by NSERC

YP8.00042 POSTDEADLINE —

YP8.00043 A Test Suite for Magnetoinertial Fusion[1] , JASON CASSIBRY, SETH THOMPSON, NILESH DHOTE, Propulsion Research Center, University of AL in Huntsville, RON KIRKPATRICK, CHARLES KNAPP, Los Alamos National Laboratory, S.T. WU, Center for Space Plasma and Aeronomy Research, University of AL in Huntsville, PROPULSION RESEARCH CENTER, UNIVERSITY OF ALABAMA IN HUNTSVILLE TEAM, LOS ALAMOS NATIONAL LABORATORY TEAM — We present a set of hydrodynamic and magnetohydrodynamic problems that will provide a set of test cases for those interested in modeling magnetoinertial fusion (MIF) plasmas. We describe several problems in cylindrical and spherical geometries, including the Noh problem, self-similar converging shocks, and magnetohydrodynamic imploding shocks. We use these models to provide physical insights into implosion dynamics of targets in the MIF parameter space. We verify MACH2 and SPH against selected cases.

[1]This work was suppored by DOE under contract DE-FG02-06ER46268

YP8.00044 Anomalous Resistivity in the Birkeland Current Regions: Fact or Fiction? Important or Unimportant? , JOHN JASPERSE, BAMANDAS BASU, Air Force Research Laboratory, ERIC LUND, Univ. of New Hampshire — In this poster, we review recent satellite data for the Birkeland current system of the earth's magnetosphere. For downward current sheets, there are three major sub regions: (1) the double-layer region (DLR); (2) the transition region (TR) just above the DLR; and (3) the long-range potential region (LRPR) that extends from the top of the TR to several earth radii and beyond. Recently, we have developed a new kinetic and fluid theory for the Birkeland current system that contains the effect of plasma turbulence. See Jasperse, Basu, Lund and Bouhram [Phys. Plasmas **13,** 072903 (2006) and Phys. Plasmas **13,** 112902 (2006)]. We apply the new fluid theory to obtain self-consistent solutions for the low-order electron and ion velocity moments and the parallel electric in the DLR and the LRPR. From the momentum balance equations in the LRPR, we find that although the anomalous resistivity exists and its value can be calculated, it plays a minor role ($<10\%$) in supporting the parallel electric field. Here, the parallel electric field is supported primarily by the mirror-force and generalized parallel pressure gradient terms in the generalized Ohm's law equation.

YP8.00045 Gamma Spectroscopy for Direct Nuclear Activation Measurements on the HERMES III and RITS 6 Accelerators[1] , KEVIN A. O'CONNOR, University of Missouri-Columbia, SALVADOR PORTILLO, Sandia National Laboratories — A gamma spectroscopy laboratory has been developed for directly measuring nuclear activation from intense electron beam sources fielded on HERMES III and RITS 6. These high brightness flash radiographic accelerators often produce photo or ion-induced activation as a result of the electron-target interactions. Materials in the diode region are activated by high energy ions accelerated towards the cathode. The resulting gamma emission from the activated samples can be measured to determine ion beam energy and density. In addition stacked copper foils fielded in and around the cathode are used as a diagnostic to infer the ion energy spectrum for energies greater than 2.2 MeV. Copper's two naturally abundant isotopes are both activated in the reactions ^{63}Cu(p,n)^{63}Zn and ^{65}Cu(p,n)^{65}Zn. The decay of both unstable zinc nuclei result in distinct gamma radiation measurable with a high purity germanium detector. The development of these capabilities, theory, and preliminary results will be presented.

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

YP8.00046 Alpha Deposition in Magnetoinertial Fusion Targets , SETH THOMPSON, PRC UAH, NILESH DEHOTE, UAH, JASON CASSIBRY, PRC UAH, RONALD KIRKPATRICK, CHARLES KNAPP, LANL, S.T. WU, CSPAR UAH, PROPULSION RESEARCH CENTER COLLABORATION, LOS ALAMOS NATIONAL LABS COLLABORATION — We performed a Monte Carlo simulation for plasmas with closed field line topology to quantify alpha deposition in magnetoinertial fusion (MIF) targets. It was assumed that the born-on position and initial velocity vector of an alpha particle is isotropic. The total energy deposited via scattering collisions is determined for a single alpha particle. This process is then repeated to achieve a statistical average. This quantity is volume averaged to get the fractional energy deposited in a target with a given set of conditions. Results were obtained for purely azimuthal, uniform and extended to field reversed configurations. Lindl-Widner diagrams were generated to identify fusion ignition regions in the MIF parameter space.

YP8.00047 Status of RF Heating and Current Drive Systems for KSTAR , YOUNG-SOON BAE, National Fusion Research Center, JIN-HYUN JEONG, SEUNG-IL PARK, MOO-HYUN CHO, WON NAMKUNG, Pohang University of Science and Technology, JONG-GU KWAK, JAE-SUNG YOON, YEONG-DUK BAE, SON-JONG WANG, SUK-KWON KIM, CHUL-KEW HWANG, SUNG-KYU KIM, Korea Atomic Energy Research Institute — The heating and current drive systems consisting of neutral beam injection (NBI) and radio frequency (RF) systems will be used for the KSTAR whose construction will be completed by August, 2007. The KSTAR RF heating and current drive systems are composed of ion cyclotron range of frequencies (ICRF), lower hybrid current drive (LHCD) system, and electron cyclotron heating (ECH) system. The KSTAR adopts the ECH-assisted start-up for the flexibility and reliability of the operation regime using 84 GHz, 500 kW gyrotron. For the KSTAR first plasma scheduled at June, 2008, two RF heating systems, 84 GHz ECH and 25-60 MHz ICRF systems, will be used for the pre-ionization to reduce the loop voltage and the wall discharge cleaning, respectively. This paper describes the status of the KSTAR RF heating and current drive systems and the initial test results using dummy load. Also, the upgrade plan of the KSTAR RF heating and current drive systems will be presented as well as the key features and the relevant technological issues for the long pulse operation.

YP8.00048 Extremely Nonsinusoidal Emissions and Fast Electron Phenomena from Strong Laser Pulses Obliquely P-Incident on Sharp-Edged Plasmas[1] , T.W. JOHNSTON, L. NIKOLIC, Y. TYSHETSKIY[2], F. VIDAL, INRS-EMT — High laser harmonic light [1] emerges when the Vulcan petawatt laser's sub-ps laser pulses are obliquely incident on slab targets with extremely low pre-pulse energy. Similar work is in progress with the ALLS 200 TW Ti-Saph laser at INRS EMT. (Pulses are 24 fs at 10 Hz with 10^{-10} contrast, even without plasma mirrors). 2-D PIC (OSIRIS code at INRS) results on basic mechanism(s) resemble those of Gibbon [2], Naumova et al. [3] and Thaury et al. [4]. The very large and asymmetric electromagnetic "spikes" which account for the high harmonic content are produced by extremely concentrated 2D plasma surface currents. The connection between our 2D PIC results (also those in [3] and 1D PIC results [2,4] using the Gibbon-Bourdier moving 1D formalism[2] is also discussed, as are the fast electrons, including some related quasi-steady magnetic fields. [1] B. Dromey et al Nature Phys. Lett., 2, 456-459 (2006) [2] Paul Gibbon, Phys. Rev. Lett. 76, 50 (1996) [3] N. Naumova, et al., Phys. Rev. Lett. 93, 195003 (2004). [4] C. Thaury, et al., Nature Phys. 3, 424 (2007)

[1]Supported by NSERC Canada
[2](now at Dept. Phys. Univ. Sydney)

YP8.00049 Semi-analytical solution of initial-value problems , JAN SCHEFFEL, Fusion Plasma Physics, Alfvén Laboratory, Royal Institute of Technology, SE-100 44 Stockholm — A fully spectral weighted residual method for solution of general initial value partial differential equations has been developed [1]. All time, spatial and physical parameter domains are represented by Chebyshev series, enabling global semi-analytical solutions. The method avoids time step limitations. The spectral coefficients are determined by iterative solution of a linear or nonlinear system of algebraic equations, for which a globally convergent root solver has been developed. Accuracy is controlled by the number of included Chebyshev modes in each dimension. The computational efficiency is shown to increase through the use of sub-domains. It is shown by example that the method may be used for efficient solution of nonlinear initial value problems in fluid mechanics and magnetohydrodynamics. [1] J. Scheffel, "Semi-analytical solution of initial-value problems," TRITA-ALF-2004-03, Royal Institute of Technology, Stockholm, Sweden, 2004.

YP8.00050 Stability and growth rates of ideal localized interchange modes[1] , MAXIM UMANSKY, LLNL — Stability of cylindrical localized ideal pressure-driven interchange plasma modes is revisited. Converting the underlying eigenvalue problem into the form of the Schrodinger equation gives a new simple way to derive the Suydam stability criterion and find the growth rates of unstable modes, using physical arguments and calculations based on elementary quantum mechanics. Near the marginal stability limit the growth rate is exponentially small and the mode has a double-peak structure.

[1]This work is performed for USDOE by Univ. Calif. LLNL under contract W-7405-ENG-48

YP8.00051 Laser-induced-fluorescence in the sheath of a thermionic Ar/O_2 Plasma. , SEBASTIAN ENGE, FARA AZIZ, ALF KÖHN, EBERHARD HOLZHAUER, ULRICH STROTH, Institut für Plasmaforschung, Universität Stuttgart, 70569 Stuttgart, Germany — In most technical plasma processes, the ion impinging energy has an important influence on the process quality. The ions gain their energy from the potential drop in the sheath region. To modify the ion energy, the substrate can be biased with a radio-frequency voltage. Furthermore, in plasma etching processes negative ions influence the sheath potential and thus the ion energy. Therefore information on the ion velocity distribution function (ivdf) in the sheath region is needed to improve the quality of plasma processing. For the investigation of the ivdf in the sheath region, a laser-induced-fluorescence diagnostic is installed on a double-plasma device. The diode laser used has an optical output of 25 mW at 668.6 nm and a mode-hop-free tuning range of 20 GHz. It is modulated with an acoustic optical modulator. The fluorescence light is collected with a PMT. For data acquisition, a 24-bit 100 kS/s PC card is used. In the first step the sheath potential has been studied in DC discharges for different fractions of negative ions in the Argon plasma. The experimental setup and first results on the sheath profile will be presented.

YP8.00052 Measurement of nonlinear energy transfer in two-dimensional plasma turbulence , PETER MANZ, MIRKO RAMSICH, ULRICH STROTH, Institut fuer Plasmaforschung, Universitaet Stuttgart, D-70569 Stuttgart, Germany — An important questions concerning the turbulent cascade is how energy is transfered among the scales. In three-dimensional fluid turbulence the energy cascades from large to small scales. Whereas in two-dimensional fluid turbulence the transfer is in the opposite direction, via an inverse cascade in, while the enstrophy is transferred by a direct cascade. In magnetised plasmas the turbulence can be assumed two-dimensional. In this work the turbulent energy cascade in simulated and experimental data from toroidally confined plasmas is studied by bispectral methods, which base on the model of three-wave interaction. General properties of the two-dimensional Hasegawa-Wakatani turbulence are recovered, which are the analytically known growth rate, dispersion relation and the direction of the energy transfer. The results from measurements in density and potential fluctuations by using a 2D probe array in the torsatron TJ-K are in good agreement with the simulated data from the Hasegawa-Wakatani turbulence. The density fluctuations, which are advected by the vorticity, show free energy transfer to smaller scales, while the $E \times B$ energy of the potential fluctuations is transferred as an inverse cascade to larger scales.

YP8.00053 Parametrics for Molecular Deuterium Concentrations in the Source Region of the UW-IEC Device Using an Ion Acoustic Wave Diagnostic , D.R. BORIS, G.A. EMMERT, Fusion Technology Institute-University of Wisconsin-Madison — The ion source region of the UW-Inertial Electrostatic Confinement device is comprised of a filament assisted DC discharge plasma that exists between the wall of the IEC vacuum chamber and the grounded spherical steel grid that makes up the anode of the IEC device. A 0-dimensional rate equation calculation of the molecular deuterium ion species concentration has been applied utilizing varying primary electron energy, and neutral gas pressure. By propagating ion acoustic waves in the source region of the IEC device the concentrations of molecular deuterium ion species have been determined for these varying plasma conditions, and high D_3^+ concentrations have been verified. This was done by utilizing the multi-species ion acoustic wave dispersion relation, which relates the phase speed of the multi-species ion acoustic wave, v_{ph}, to the sum in quadrature of the concentration weighted ion acoustic sound speeds of the individual ion species.

YP8.00054 Neoclassical Conductivity and Fraction of Trapped Particles for Damavand Tokamak. , FATEMEH DINI, Amirkabir University of Technology, SINA KHORASANI, Sharif University of Technology, AMIRKABIR UNIVERSITY OF TECHNOLOGY COLLABORATION, SHARIF UNIVERSITY OF TECHNOLOGY COLLABORATION — The Spitzer or classical conductivity is the conductivity of cylindrical plasma column. The neoclassical theory, taking into account the toroidal geometry of the plasma, predicts under certain conditions the existence of so–called banana particles, which are trapped in the magnetic field and do not contribute to the plasma conductivity. Here, the best proposed expression for the neoclassical conductivity in terms of fraction trapped particle has been used. A standard model for the Damavand Tokamak plasma equilibrium, with large-aspect-ratio and elongation (A∼5.1, k∼1.2), is considered for evaluating averaged magnetic field in flux coordinates. Analytical and numerical calculations have been obtained using integration of ellipticity function within the approximation of large aspect ratio and zero-shift of flux surfaces for Damavand Tokamak.

YP8.00055 Long time electron cloud instability simulation using QUICKPIC with pipelining algorithm

, BING FENG, University of Southern California, P. MUGGLI TEAM, T. KATSOULEAS TEAM, V. DECYK COLLABORATION, C. HUANG COLLABORATION, W. MORI COLLABORATION — We proposed a novel algorithm, which uses pipelining to reduce the simulation time for beam-electron cloud interaction. In the pipelining algorithm the processors are divided into subgroups, and during the simulation different groups will be on consecutive time steps. The pipelining algorithm is applied to the fully parallelized Particle-In-Cell (PIC) code QuickPIC to overcome the limit of the number of processors that can be used at each time step. With the new algorithm, the accuracy of the simulation is preserved; and the speed of the simulation is improved by a factor proportional to the number of processors available. The long term beam evolution results for the CERN-LHC using the QuickPIC with pipelining algorithm are presented.

YP8.00056 Penumbral Dynamics and its Manifestation in the Overlying Chromosphere

, MARGARITA RYUTOVA, LLNL/IGPP, THOMAS BERGER, THEODOR TARBELL, ZOE FRANK, ALAN TITLE, LMSAL — Mature sunspots are usually surrounded by penumbra - a dense conglomerate of a random interlaced flux tubes with varying inclinations. High resolution observations show a fine sub-structure of penumbral filaments and new regularities in their dynamics. These regularities fit well our recent model of penumbra based on cascading reconnection events occurring in the system of non-collinear flux tubes. Each act of reconnection generates twist in the reconnected filaments and facilitates the onset of a screw pinch instability, consistent with the observations showing that individual filaments are cylindrical helices with a pitch/radius ratio providing their stability. In addition, the post-reconnection products produce a sling-shot effect that generates oblique shocks and leads to appearence of a lateral jets. Here we report high resolution (120-180 km) high cadence (15-30 sec) observations taken with the Solar Optical Telescope (SOT) on the Hinode satellite. Co-aligned multi-hour movies taken simultaneously in several wavelengths show detailed behavior of penumbra filaments and their effect on the overlying chromosphere. We confirm the ubiquitous nature of penumbral micro-jets recently discovered by SOT instrument (Katsukawa et al. 2007, AAS 210, 94.13), and present quantitative analysis of chromospheric jets based on our recent model of penumbra.

YP8.00057 A Simulation Study of Hall Effect on Double Tearing Modes[1]

, ZHIWEI MA, Institute of Plasma Physics & Zhejiang Univ., CHENGLONG ZHANG, Zhejiang Univ., JIAQI DONG, Southwestern Institute of Physics — The Hall magnetohydrodynamics (MHD) simulation is carried out to study the dynamic process of a double tearing mode. The results indicated that the growth rates in the earlier nonlinear and transition phases agree with previous results. With further development of reconnection, the current sheet thickness is much smaller than the ion inertia length, which leads to a strong influence of the Hall effects. As a result, the reconnection in the late nonlinear phase exhibits an explosive nature with a time scale nearly independent of resistivity. A localized and severely intensified current density is observed and the maximum kinetic energy is over one order of magnitude higher in Hall MHD than in resistive MHD.

[1]Institute of Plasma Physics

YP8.00058 Investigation of X-ray lasers on the SOKOL-P facility at RFNC-VNIITF

, D.S. GAVRILOV, A.V. ANDRIYASH, D.A. VIKHLYAEV, S.A. GOROKHOV, D.A. DMITROV, A.L. ZAPYSOV, A.G. KAKSHIN, I.A. KAPUSTIN, E.A. LOBODA, V.A. LYKOV, V.YU. POLITOV, A.V. POTAPOV, V.A. PRONIN, G.N. RYKOVANOV, V.N. SUKHANOV, A.S. TISCHENKO, A.A. UGODENKO, O.V. CHEFONOV, RFNC-VNIITF COLLABORATION — The experiments [1] have demonstrated generation of the laser X-radiation (LXR) λ=326A on 3p-3s transitions of Ne-like Ti ions at sequential irradiation of the targets by two laser pulses, focused into a narrow line. The small signal gain equaled 30cm^{-1}. The intensity was $0.5{\cdot}10^{12}$ W/cm^2 in the prepulse of 0.4ns and 10^{14} W/cm^2 in the master pulse of 4ps (delay 1.5 ns). The dependence of LXR yield on the laser energy is demonstrated to have an exponential form. The traveling pumping wave mode was realized using the reflective echelon and the LXR yield is as great as 5-fold. The latest experiments have demonstrated the LXR generation on 4d-4p of Ni-like molybdenum λ=189A. The development of LXR generation model, and numerical codes which allow for the quanta delay effects, quanta refraction in plasma with heavy density gradient, and also the saturation effect have made it possible to describe the experimental dependence of the output LXR yield on the active medium length. Good quantitative agreement is also evident when estimating the output LXR yield on Ne-like Ti ions. [1]Andriyash Quantum Electronics 36 511

YP8.00059 Laser heating of solid matter by light pressure-driven shocks at ultra-relativistic intensities

, K. AKLI, General Atomics, M. KEY, A. KEMP, S. HANSEN, LLNl, R. STEPHENS, General Atomics, R. FREEMAN, OSU, F. BEG, UCSD, D. CLARK, OSU, D. HEY, S. HATCHETT, LLNL, K. HIGHBARGER, OSU, E. GIRALDEZ, General Atomic, J. GREEN, G. GREGORI, K. LANCASTER, RAL, T. MA, UCSD, A. MACKINNON, LLNL, P. NORREYS, RAL, P. PATEL, LLNL, C. STOECKL, W. THEOBALD, LLE, R. WEBER, L. VAN WOERKOM, N. PATEL, OSU, M. STORM, LLE — Heating by irradiation of a solid surface in vacuum with 5x10^{20} Wcm^{-2}, 0.8 ps, 1.05 micron wavelength laser light is studied by x-ray spectroscopy of the K-shell emission from thin layers of Ni, Mo and V. A surface layer is heated to $\sim$5 keV with an axial temperature gradient of 0.6 μm scale length. Images of Ni Lyα show the hot region has a $\sim$25 μm diameter. These data are consistent with collisional particle-in-cell simulations using pre-formed plasma density profiles from hydrodynamic modeling, which show that the more than 100 *Gbar* light pressure compresses the preformed plasma and drives a shock into the solid heating a thin layer.

YP8.00060 Microwave Soliton Generation and Propagation in a Cylindrical Partially Plasma Filled Waveguide

, SEYED MORAD-ALI HASHEMI, K. N. Toosi University of Technology, Tehran, Iran — A perfect electrical conductor (PEC) cylindrical waveguide with a radius of r_1 is considered as the main part of a basic microwave generator model in the cylindrical geometry which supports the axial movement of an electron beam of radius $r_2 \leq r_1$ inside it. Using fluid theory of plasma, it has been shown that this structure is capable of supporting nonlinear Schrödinger (NLS) soliton generation and propagation. The wave equation for the vector potential **A** has been derived using plasma dispersion relation. The equation has then been separated into two different equations in the transverse and axial directions, considering a solution in the form of a function of transverse variables multiplied by another time dependent function of axial variable, the latter itself having two components: a fast oscillation with a slowly varying amplitude. Once β, the propagation constant in the axial direction, obtained by applying boundary conditions in the former equation, the latter equation can be manipulated by imposing a perturbation on the dielectric constant. This will result in a perturbation on propagation constant which in turn will induce to the calculations the nonlinear term required for NLS equation in the form of a pondermotive force, completing derivation of the required NLS equation supporting the soliton formation and propagation.

YP8.00061 Direct Observation of Electron Bernstein Wave on the Internal Coil Device Mini-RT

, EIICHI YATSUKA, DAISUKE SAKATA, KIYOTAKE KINJO, Graduate School of Frontier Sciences, University of Tokyo, JUNJI MORIKAWA, YUICHI OGAWA, High Temperature Plasma Center, University of Tokyo — Electron Bernstein Wave (EBW) heating is one of the most promising methods of producing and heating of overdense plasma, i.e., the plasma density is higher than a cut-off density. Overdense plasma was observed with steep density gradient by ECH (2.45GHz, 2.5kW) in internal coil device Mini-RT. Directly measurements of electric field with electron cyclotron range of frequency were carried out, in order to investigate the basic characteristics of mode conversion to EBW. An extra microwave (1.0$\sim$2.1GHz, 10W) has been injected with an excitation antenna, and has been directly measured with a receiver antenna inside the plasma column. With the combination of floating and levitation coils, which are located inside and above the vacuum vessel, we can produce a separatrix configuration with a steep density gradient, which is one of important parameters on the EBW mode conversion. With appropriate magnetic configuration and density profile, we can see a characteristic of a short wavelength related with the EBW. In addition, the reversal of phase variation can be observed. Since the EBW is backward wave (direction of phase velocity is opposite to that of group velocity), these experimental results suggest the direct measurement of the EBW.

YP8.00062 Magnetohydrodynamic Waves Driven by CW AM Modulation of Helicon Plasmas , SAEID HOUSHMANDYAR, ALEX HANSEN, EARL SCIME, West Virginia University — Nonlinearly interacting, low-frequency, magnetohydrodynamic waves, and the resultant cascade of energy to larger perpendicular or parallel wave numbers, have been suggested as a possible explanation for electron and/or ion heating in the expanding solar corona. In experiments undertaken in HELIX (Hot hELIcon eXperiment), we have explored the possibility of exciting large amplitude, low-frequency waves in a high density helicon plasma through the continuous-wave AM modulation of the rf antenna of a helicon plasma source. Magnetic fluctuation measurements indicate that low frequency waves are excited in helium helicon plasmas at the AM modulation frequency. We will present measurements of the parallel and perpendicular wave numbers obtained from ensemble-averaged measurements as a function of AM frequency, background magnetic field strength, and neutral gas pressure. No resonant behavior is observed for AM frequencies close to the helium ion cyclotron frequency.

YP8.00063 Turbulent transport of energetic particles in global gyrokinetic particle simulations , WENLU ZHANG, University of California, Irvine, VIKTOR DECYK, University of California, Los Angeles, YASUTARO NISHIMURA, ZHIHONG LIN, University of California, Irvine — Multi-species capability has been added to the gyrokinetic toroidal code (GTC), which has been applied to study the behavior of energetic particles in burning plasmas. The effect of microscopic ion-temperature-gradient (ITG) turbulence on energetic particles transport is investigated using the large scale gyrokinetic particle simulations.

YP8.00064 Nonextensive Thomas-Fermi model , BHIMSEN SHIVAMOGGI, EVGENY MARTINENKO, University of Central Florida — Nonextensive Thomas-Fermi model was father investigated in the following directions: Heavy atom in strong magnetic field. following Shivamoggi work on the extension of Kadomtsev equation we applied nonextensive formalism to father generalize TF model for the very strong magnetic fields (of order 10e12 G). The generalized TF equation and the binding energy of atom were calculated which contain a new nonextensive term dominating the classical one. The binding energy of a heavy atom was also evaluated. Thomas-Fermi equations in N dimensions which is technically the same as in Shivamoggi (1998) ,but behavior is different and in interesting 2 D case nonextesivity prevents from becoming linear ODE as in classical case. Effect of nonextensivity on dielectrical screening reveals itself in the reduction of the envelope radius. It was shown that nonextesivity in each case is responsible for new term dominating classical thermal correction term by order of magnitude, which is vanishing in a limit q->1. Therefore it appears that nonextensive term is ubiquitous for a wide range of systems and father work is needed to understand the origin of it.

YP8.00065 Plasma dynamics in DUSTWHEEL , F. GREINER, IEAP CAU Kiel, Germany, S. KNIST, A. PIEL, IEAP CAU-Kiel, Germany — The new experiment DUSTWHEEL consists of a set of 24 water-cooled magnets, which produce a steady-state magnetic field of $\mathbf{B} \leq 0.7$T that is homogeneous over a length of L = 1 m. DUSTWHEEL has a special design for the investigation of drift or flute modes under the influence of a dusty plasma environment. In contrast to other plasma constituents dust particles are strongly affected by gravitation. To deal with this the magnets of DUSTWHEEL are suspended in a wheel-shaped cage, which allows tilting the entire experiment. In this way, the angle between the magnetic field direction and gravity can be chosen at will. This allows exciting dust flows by a variation of the residual component of gravity. The plasma in DUSTWHEEL is produced by means of a capacitive high frequency discharge at 13.56 MHz. The low density plasma has a Gaussian shaped density profile with a peak density of $4\ 10^{14}\ m^{-3}$. The electron temperature is nearly constant with a value of circa $4\ eV$. A detailed analysis of density and potential fluctuations using Langmuir probes shows a turbulent plasma state with almost no mode like behavior. As a control parameter to get different dynamic states a biasing voltage can be applied to the plasma. In this way the plasma can also be driven to mode-like states. Amplitude and structure Analysis reveals that the structures have drift wave dynamics. So, DUSTWHEEL is ready to put dust inside and study the modification of drift waves.

YP8.00066 Photoelectron Plasma for Antiproton Cooling in Antihydrogen Production , BENJAMIN LEVITT, Harvard University, ATRAP COLLABORATION — A new photocathode electron source has been developed for antiproton cooling for antihydrogen production in the ATRAP2 Penning trap apparatus. Ten-nanosecond pulses of photoelectrons liberated by intense UV laser pulses from a thin gold layer are captured into a single-component plasma. Up to a billion electrons are accumulated using a series of laser pulses, more than are needed for efficient p cooling. The method is demonstrated within an enclosed vacuum space that is entirely at 4 K, and is thus compatible with the exceptional cryogenic vacuum that is desirable for the long-term storage of antihydrogen. The pitfalls of other electron accumulation methods are entirely avoided, including the particle heating and declining efficiency of field emission point loading, and the heat load and contamination of thermionic emission methods. We also report on other recent ATRAP results, including antiproton stability and antihydrogen production inside a quadrupole Penning-Ioffe trap.

YP8.00067 Quantification of factors contributing to the x-ray spot produced by the paraxial diode with a plasma-filled drift cell , DAVID SHORT, Atomic Weapons Establishment, DALE WELCH, Voss Scientific — The paraxial diode with a plasma-filled drift cell is currently under investigation as a focusing element for the HRF at AWE Aldermaston. The long term x-radiographic goal is for an x-ray dose of 1000 Rads@1m in a 2mm spot. To meet this the plasma-filled drift cell needs to provide complete space charge and current neutralization. In this manner the electrons will focus ballistically meeting at a common focus within the plasma drift cell [1]. However, any time variation in current neutralization, due to a finite magnetic diffusivity, will result in some degree of focal sweep and an increased spot size at the high Z target. The work presented here will attempt to quantify this factor and any other effects that impact the spot on the high Z target. Computer simulations are carried using the particle in cell code Lsp [2]. An idealized beam injection into the drift cell was used to examine the effect perfect entrance conditions would have on the focusing spot. The findings indicate that the plasma-filled paraxial using a flat plate cathode is likely to give a total time integrated spot of around 3mm. Updates on the latest simulations are also discussed. [1]. D.Welch *et al.* Transport of a relativistic electron beam in gas and plasma-filled focusing cells for x-radiography, Phys.Plasmas, **11**, pp 751-760 (2004) [2]. Lsp is a software product of Mission Research Corporation, www.mrcabq.com

YP8.00068 Remarks on the Scaling of Kurtosis with Squared Skewness[1] , J.A. KROMMES, Princeton University — Recent analysis of density fluctuations in TORPEX[2] support the relationship $K = aS^2 + b$ between the skewness S and (excess) kurtosis K, where $a \approx 1.5$ and $b \approx -0.2$. (A realizability constraint is $K \geq S^2 - 2$.) Remarkably, essentially the same result has been shown to hold for a global dataset of fluctuations of sea-surface temperature,[3] and a simple theoretical (nonlinear Langevin) model has been proposed[3] that leads to $a = 3/2$ and $b = 0$. This is obviously suggestive, but it is a challenge to justify the Langevin model in detail for magnetized plasma turbulence. Previous results on higher-order statistics,[4] dimensionally compatible with $K \sim S^2$, are reviewed and an attempt is made to derive a and b for a model involving coupled modes and linear waves. The extent to which the values of a and b are sensitive discriminants for details of the underlying turbulence is discussed.

[1]Work supported by U.S.D.o.E. Contract No. DE-AC02-76-CHO-3073.

[2]B. Labit *et al.*, Universal statistical properties of drift-interchange turbulence in TORPEX plasmas, Phys. Rev. Lett. **98**, 255002 (2007).

[3]P. Sura and P. D. Sardeshmukh, A global view of non-Gaussian SST variability, J. Phys. Oceanogr.(2007), in press.

[4]J. A. Krommes, Non-Gaussian statistics, classical field theory, and realizable Langevin models, Phys. Rev. E **53**, 4865 (1996).

YP8.00069 Stability Analysis of Laser Driven Radiative Shocks in High Energy Density Plasmas , ROBERT LUNSFORD, Research Support Instruments, J. MARTIN LAMING, JACOB GRUN, Naval Research Lab, CHARLES MANKA, SERGEI NIKITIN, GELU COMANESCU, R.S.I. — An experiment has been undertaken at the Naval Research Laboratory which looks to investigate the applicability of present analytic models to various multidimensional radiative instabilities within the interstellar medium. The primary focus at this juncture is the examination of a velocity dependant cooling instability thought to cause amplitude fluctuations within the overall shock propagation velocity. The PHAROS laser at NRL is utilized to create the relevant shock front by ablative deconstruction of an aluminized Mylar foil placed at the front of a tunnel within a PMMA block. This primary front launches secondary shocks into the walls of the tunnel and the pressure gradient created within the PMMA is recorded utilizing dark field shadowgraphy on a SIM-8 multi-channel high speed framing camera. It is a deviation from linearity in this secondary front which can be interpreted as a instability in the propagation velocity.

YP8.00070 Electron Acoustic Waves Inside a Plasma Sheath Around a Hypersonic Vehicle[1] , VLADIMIR SOTNIKOV, University of Nevada at Reno — High plasma density inside a plasma sheath around a hypersonic vehicle prevents electromagnetic waves with the frequencies below the local plasma frequency to propagate in this layer. This creates serious communication problems. One of the possibilities to mitigate this problem is to create two temperature electron plasma inside a sheath to allow electron acoustic waves to propagate through a plasma layer. Excitation, propagation and attenuation of electron acoustic waves inside a plasma sheath in the presence of an electron beam will be discussed.

[1]This work was funded in part by AFOSR, contract # FA9550-07-C-0049.

YP8.00071 Plasma Dynamics of Translation process of Field-reversed Configuration , KEN SAKURABA, Nihon University — To form high performance FRC plasmas with electron density of 10^{20}m^{-3} and low background neutral particles, a field-reversed theta pinch device, called NUCTE-III, modified and a confinement region with a quasistationary magnetic field is installed. A FRC translation experiment with super-Alfvenic velocity started. Initial experiment results are presented. FRC plasma, which has electron density of $\sim$2.5x10^{21} m^{-3}, total temperature of 200 eV, poloidal flux of 0.5 mWb, separatrix radius of 0.05 m, plasma volume of 4x10^{-3} m^3, has been translated with the first path velocity of 150 km/s, and the second path one of 50 km/s and settled down after two times reflections. Plasma volume, poloidal flux and separatrix radius of settled down FRC become $\sim$4x10^{-2} m^3, 0.23 mWb and $\sim$0.1 m, respectively. The plasma had a lifetime of about 0.1ms and terminated by the growth of n=2 rotational instability. The velocity was yet a half of Alfven one. High performance FRC plasma, which is formed on TCS, has not yet obtained. By the excluded flux and visible light optical measurements, dynamics of the translation process has been investigated.

YP8.00072 ECRH and its Effects on Neoclassical Transport in a Stellarator[1] , JAECHUN SEOL, National Fusion Research Institute, C.C. HEGNA, J.D. CALLEN, University of Wisconsin-Madison — A direct loss flux can be generated from energetic electron population in a stellarator. Thus energetic electron populations can substantially modify the neoclassical transport properties in stellarators. A model accounting for this change in transport is developed assuming the presence of electron cyclotron resonance heating (ECRH). The quasilinear diffusion coefficient for second harmonic X- mode ECRH is developed for a bumpy stellarator. Care is taken in accounting for the pitch-angle dependence of the quasilinear diffusion coefficient since application to experiments with narrow resonance zones is of interest. For trapped particles in a three dimensional configuration, collisionless loss zones exist in velocity space. Radio-frequency (rf) waves accelerate trapped electrons into the direct loss zone in bumpy stellarators and produce a direct loss flux. An analytic expression for this loss flux is derived; it is proportional to the rf field strength and the value of the zeroth order distribution function at the minimum speed for collisionless loss. The direct loss flux of electrons is another source of a non-ambipolar particle flux in bumpy stellarators. This additional non-ambipolar flux modifies the ambipolarity equation which generally has multiple roots for the radial electric field. An electron root (large positive E_r) is easily obtained if the electrons are in the $1/\nu$ regime and the ions are in the ν regime.

[1]This research was supported by the U.S. DoE under Grant No. DE-F02-99ER54546.

YP8.00073 Identification of the parametric-modulational instability of the drift wave-zonal flow system in a cylindrical magnetized plasma[1] , Y. NAGASHIMA, S.-I. ITOH, S. SHINOHARA, Kyushu University, M. FUKAO, Uji, Kyoto, A. FUJISAWA, NIFS, T. NISHIZIMA, K. TERASAKA, M. KAWAGUCHI, Y. KAWAI, Kyushu University, G.R. TYNAN, P.H. DIAMOND, UCSD, M. YAGI, S. INAGAKI, T. YAMADA, T. MARUTA, K. KAMATAKI, Kyushu University, K. ITOH, NIFS — We present observation of the parametric-modulational instability of the drift wave-zonal flow system in the Large Mirror device of Kyushu University. Linear dispersion relations of observed fluctuations are consistent with theoretical predictions of meso-scale residual zonal flow and micro-scale drift-wave. Oscillation of the zonal flow potential is synchronized at modulations of amplitude, radial wavenumber, and turbulence Reynolds stress per mass density of the drift-wave. The bispectral analysis reveals nonlinear energy transfer from the drift-wave into the zonal flow at a radial location where the zonal flow forms a shear structure. Non-local energy transfer to turbulence via “zonal flow channel” is also discussed.

[1]This work was partly supported by the Grant-in-Aid for Specially-Promoted Research (16002005) of MEXT, and by the Grant-in Aid for Young Scientist (B) (18760637) of MEXT, Japan.

YP8.00074 Application of Optical Emission Diagnostics to Study Effects of Foils on Self Magnetic Pinch E-Beam Diode Operations. , A.D. HEATHCOTE, A.D.J. CRITCHLEY, Atomic Weapons Establishment, M.D. JOHNSTON, Sandia National Laboratories — Optical diagnostics are being developed and deployed at AWE to explore the limiting physics of electron beam diodes used for flash x-ray radiography. Photodiode and imaging systems have been used to observe plasma emission from the diode anode cathode (A-K) gap during x-ray production ($\sim$100 ns) and for several microseconds beyond. There is currently a paucity of experimental data [1] direct from A-K gap plasmas; these data are needed to enhance understanding of the limiting physics of the diode geometries. Spatially and spectrally resolved intensity data from the A-K gap of self magnetic pinch (SMP) diodes has been collected and is presented. This has been used to study the role of foils used within the diode assembly and their role in inhibiting diode impedance collapse [2] for improved integrated dose output. [1] - Martin P, Short D, Jones A – Theory Underpinning Ongoing Fundamental Pinch Physics Research at AWE, November 2005 to August 2006. Ref: AWE/HD02/B/0607/812. [2] - I. Crotch et al., “Self Magnetic Pinch Diode Experiments at AWE”,14th IEEE Int. Pulsed Power Conf., 2003, pp. 507-509.

YP8.00075 A New Shearing Interferometer for Cylindrical Wire Array Experiments[1] , S. PIKUZ, T. SCHELKOVENKO, P. SCHRAFEL, B. KUSSE, Cornell University — In standard shearing interferometry, part of a single probing beam passes through a perturbing medium and is then split into two beams. A linear shift results in an overlap, interference and a fringe pattern yielding the perturbing medium density profile. The probing beam needs to be larger than the perturbing medium so that part of it passes through a well separated, low density region. During early time axial views of imploding cylindrical wire arrays the low and high density regions are not well separated. The low density regions lie in between the high density regions that are near the initial wire positions. In addition, the probing beam diameter is comparable to the array diameter. In this case a linear translation will not work but the overlap can be accomplished by an azimuthal rotation of one beam with respect to the other. Such an azimuthal shearing interferometer has been bench tested with encouraging results. A refined version has been set up on the COBRA experiment to give time resolved, radial and azimuthal electron density profiles during early time, cylindrical wire array implosions.

[1]Supported by NNSA SSAA DOE Cooperative Agreement DE-FC03-02NA00057

YP8.00076 Plasma operation in a divertor tokamak with all tungsten plasma facing components , R. NEU, W. BOBKOV, R. DUX, T. EICH, H. GREUNER, O. GRUBER, A. HERRMANN, L. HORTON, A. KALLENBACH, M. KAUFMANN, P. LANG, C. F. MAGGI, H.-W. MUELLER, R. PUGNO, T. PUETTERICH, V. ROHDE, W. SCHUSTEREDER, A.C.C. SIPS, J. STOBER, W. SUTTROP, M. WISCHMEIER, H. ZOHM, MPI fuer Plasmaphysik, Euratom Association, Garching, Germany, ASDEX UPGRADE TEAM — To investigate plasma wall interaction with tungsten plasma facing components and its implications in a divertor tokamak, ASDEX Upgrade has been completely equipped with W coated tiles. A range of tools has been developed to allow for discharges with good confinement combined with acceptable W concentrations. After the implementation of W ICRH- and guard-limiters, they were identified as the main W sources during operation of ICRH. This is attributed to the acceleration of intrinsic impurities in the rectified parasitic electrical field leading to an increased W sputtering yield. During the last vent deposited layers were removed from the W surfaces and the start-up of the 2007 campaign was performed without prior boronization. Although all primary carbon sources are removed, almost no reduction of the C concentrations is observed up to now. H-Modes with $H \approx 1$ and a moderate W content could be obtained soon after the first pulse with auxiliary heating and detailed investigations on the W influxes and their impact were performed.

YP8.00077 Observation of Recurring Phase-Inversions in Radiatively Heated Single-Mode Sinusoidal Perturbations , N.E. LANIER, J. WORKMAN, S.D. CROCKETT, R.L. HOLMES, R.N. MULFORD, B. PATTERSON, D. SCHMIDT, D. SWIFT, Los Alamos National Laboratory, P. GRAHAM, A. MOORE, Atomic Weapons Establishment — Experiments studying the hydrodynamic evolution of radiatively heated single-mode perturbations have been conducted at the OMEGA laser facility. An epoxy layer with a sinusoidal interface is embedded in foam and heated with tin L-shell radiation. As the epoxy expands, an optional shock, with independently controlled strength and timing, is introduced. The resulting hydrodynamic behavior is radiographically. Experimental data along with three-dimensional RAGE simulations are used to generate a more complete picture of this preheat-induced evolution. When preheated, the initial expansion of the sinusoidal perturbation forms a complex set of shocks and an interface that quickly becomes non-linear. The interaction of these preheat-induced shocks result in density gradients, whose phase, with respect to the initial perturbation, oscillates in time. In this experiment, when the shock propagates through the evolving layer, these density gradients are the dominant influence on post-shock hydrodynamic behavior. This work is sponsored by U. S. DOE under Contract No. DE-AC52-06NA25396.

YP8.00078 Outline for a Spheromak Proof of Principle Experiment[1] , SIMON WOODRUFF, ANGUS MACNAB, Woodruff Scientific, LLC — A possible means for reducing reactor core complexity and size (and hence cost) could lie with research into the Spheromak concept: a plasma ring with no coils linking the plasma. Much progress has been made in the last 20 years, and now tokamak-like confinement is being reported, with work focusing on understanding beta-limits, transport and novel means of generating magnetic fields both in sustained and pulsed scenarios. Spheromak research is maturing, with many experiments integrated into a national program to resolve well defined critical physics issues. This poster summarizes the work from the last 20 years both as a historical overview and an outline of the present status. A natural consequence is to suggest the possibility of a Next-Step Spheromak, or advanced Proof of Principle device that will build on recent success and address many of the remaining critical issues in preparation for a Spheromak BPX.

[1]This work is privately supported.

Friday, November 16, 2007 12:35PM - 12:45PM –
Session ZE1 Door Prizes Drawing Rosen Centre Hotel Junior Ballroom

12:35PM ZE1.00001 Door Prizes Drawing –